

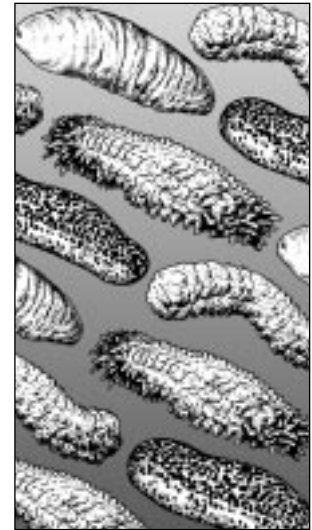


FISHERIES PROGRAMME  
INFORMATION SECTION

# BECHE-DE-MER

Number 8 — April 1996

INFORMATION BULLETIN



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## NOTE FROM THE EDITOR

Welcome to the eighth issue of the *Beche-de-mer Information Bulletin*. This issue contains several contributions in various areas, which cover sea-cucumber biology and fishery, and are arranged as in previous issues in three major sections: new information, correspondence and publications.

Several articles from around the region have been extracted from working papers presented at the recent joint South Pacific Commission – Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries, held in Noumea in June/July 1995.

The management of these fisheries raises problems in many Pacific countries and territories, as seen in Papua New Guinea (p. 2), Vanuatu (p. 11) and Indonesia (p. 17), as well as Galapagos (see *Beche-de-mer Information Bulletin* #7), where the situation is still very disquieting. These issues will certainly be discussed at a symposium on echinoderm fisheries and mariculture planned for the next International Echinoderm Conference (San Francisco, August 1996) (p. 50).

Following the article on the spawning of *Cucumaria frondosa*, other aspects of its reproductive biology are presented here (p.22).

The rubrique 'Spawning observations' (p. 41) again contains helpful information, and the first reply to the request for 'fission and regeneration observations' (see *Beche-de-mer Information Bulletin* #7) provides new data for *Holothuria atra*.

Chantal Conand

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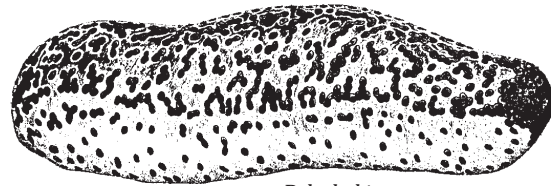
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B E C H E - D E - M E R

## I N F O

*Bohadschia argus*

## SEA-CUCUMBER FISHERIES IN THE SOUTH PACIFIC

The next four articles are extracts of papers presented during the SPC- FFA Workshop on the Management of South Pacific Inshore Fisheries, which was held in Noumea in June/July 1995. Two volumes of country and background papers from the workshop will be published by SPC in early 1996.

**Illegal fishing for sea-cucumber (beche-de-mer)  
by Papua New Guinea artisanal fishermen in  
the Torres Strait protected zone**

by Paul Lokani<sup>1</sup>

#### INTRODUCTION

The Torres Strait Islands stretch from Cape York in Australia to Western Province in Papua New Guinea (PNG). The Torres Strait Islands were annexed by Queensland between 1872 and 1879 with the border running within three kilometres of the Papuan coast. This was because the best fishing grounds for pearls, trochus and beche-de-mer lay in the northern portion of the strait (Johannes and MacFarlane, 1991).

Under the treaty signed by Australia and PNG in 1978 and ratified in 1985 (Haines, 1986; Johannes and MacFarlane, 1991) the border was shifted south to the present border (figure 1). A consequence of the international border between Queensland (and later Australia) and PNG was the implication on traditional fishing activities in what is now known as the Torres Strait Protected Zone.

This area was traditionally fished by Torres Strait Islanders and their relatives in the coastal villages of the Western Province, Papua New Guinea. The Torres Strait Treaty, however, acknowledged and recognised and protected the rights of these people to freely carry out traditional activities including traditional fishing in the area, as they have done so for generations.

The largest reef system within the Torres Strait Protected Zone is the Warrior Reef complex stretch-

ing from north to south. These reefs are extensively fished for dugongs, turtles and fish by the coastal villages of the Western Province. In 1990, an artisanal beche-de-mer fishery involving both fishermen addressed in the Torres Strait Treaty as traditional users and those from outside the treaty arrangement, exploited sandfish (*Holothuria scabra*) at the Warrior Reef. The fishery was based in Daru, with fishermen using banana boats and traditional outrigger canoes to fish and transport the catch to Daru for processing and sale. Harvesting involved walking on the reef during low tide and sometimes snorkelling in shallow waters.

In what is attributed to low catch rates of the more valuable, larger sandfish, fishermen started fishing illegally on the Australian waters of the Warrior Reef in 1991. This resulted in Australian authorities stepping up patrols in the area, which resulted in apprehension of fishermen, confiscation of fishing gear and prosecution of fishermen. The incidence and patterns of illegal fishing in Australian waters of the Warrior Reef and its implications are discussed in this paper.

#### INCIDENCE OF ILLEGAL FISHING

Sightings of illegal beche-de-mer fishing were reported two years after the fishery commenced, but fishermen indicated that illegal fishing occurred as early as 1991. This appears to be a case of typical behaviour by fishermen, where their fishing is se-

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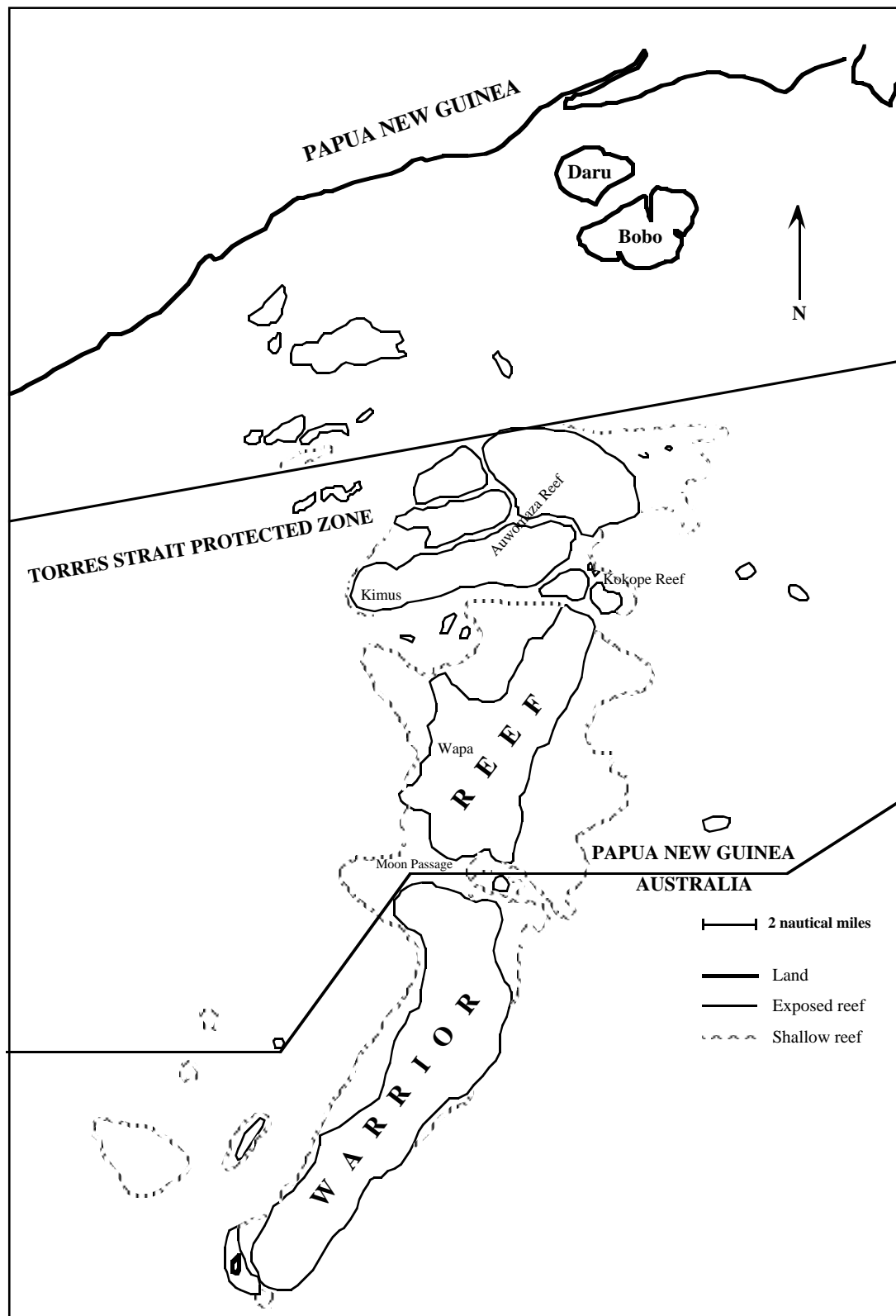


Figure 1: Map showing the Warrior Reef and its two major reefs, Auwomaza and Wapa

lective and they try to maximise catch. At the Warrior Reef there was a spatial shift in effort in a north-south direction, attributed to over-fishing from the north of the Warrior Reef which progressed south. This progression is economically valid because

Daru, which is the main centre of trade for beche-de-mer, lies north from the Warrior Reef (see figure 1).

Illegal fishing continued through to the closure of the fishery in 1993. Illegal fishing activities de-

creased after increased patrols by the Australians, and after the apprehension of large numbers of fishermen, but did not stop.

Both day- and night-time poaching of sea cucumbers occurred. As soon as the apprehension of PNG fishermen commenced, most of the day-time poaching occurred at sunset after the Australian Customs plane flew its random weekly patrols on both sides of the Torres Strait Protected Zone. Night-time poaching occurred when the tide was not favourable for day-time poaching, and especially after the Australians increased patrols, poaching was timed with low tide as this allowed for fast collection.

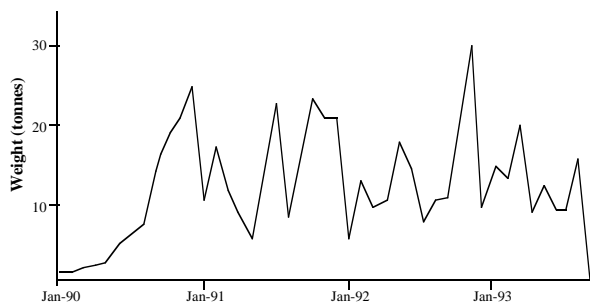
Illegal fishing co-incided with the first rapid decline in production in 1991 (Lokani, unpublished data) [see figure 2].

#### APPREHENSIONS

Increased patrols in the area by Australian authorities resulted in the apprehension of offending Papua New Guinean beche-de-mer fishermen. The first successful apprehension was on 2 September 1992. From a total of 35 fishermen apprehended by Australian authorities, only the seven skippers of the boats were prosecuted. The rest of the fishermen were cautioned and released. The first apprehensions did not deter illegal fishing, which continued to occur. This resulted in more apprehensions from 1992 until 1993 (table 1 & 2).

#### IMPLICATIONS TO THE TORRES STRAIT TREATY

Implementation of the Torres Strait Treaty is carried out by PNG, the Queensland Department of Primary Industries [QDPI] and the Commonwealth of Australia. In PNG, the Fisheries Resources are regulated through the Torres Strait Fisheries Act of PNG, the Fisheries Act and the Continental Shelf Act.



**Figure 2: Monthly production (dry-weight tonnes) landed at Daru from 1990 to September 1993 (the fishery was closed in September 1993)**

**Table 1: Number of fishermen apprehended by Australian authorities**

Month	Number of Fishermen apprehended
2 September 1992	35 (7 prosecuted in Australia, rest released)
18 November 1992	8 (prosecuted in Australia)
November 1992	23 (prosecuted in PNG)
16 December 1992	39 (prosecuted in Australia)
December 1992	58 (prosecuted in PNG)

**Table 2: Boat types confiscated by Australian authorities on 12 December 1992**

Boat type	Engine (HP)	Length (metres)	No. of fishermen
<i>Banana</i>	40	6	6
<i>Banana</i>	25	6	5
<i>Banana</i>	40	6	5
<i>Banana</i>	25	6	5
<i>Banana</i>	30	6	4
<i>Outrigger</i>	30	8	10
<i>Outrigger</i>	30	9	9
<i>Outrigger</i>	15	9	8

PNG prosecuted offending PNG fishermen, as stipulated in Article 28, paragraph 6 of the Torres Strait Treaty: 'Corrective action in respect to offences or suspected offences against the fisheries laws or regulations of the Parties shall be taken by the authorities of the Party whose nationality is borne by the vessel or person concerned (called in this article 'the First Party') and not by the Party in whose jurisdiction the offence or suspected offence occurs (called in this Article 'the Second Party'). Australian officers overlooked this clause, and prosecuted some fishermen in Australia. The balance of the offending fishermen were prosecuted in PNG by PNG authorities.

Legal and prosecuting costs are effectively transferred back to the country of the offending fishermen. It was, therefore, in the interest of PNG that all measures were taken to introduce a moratorium in September 1993 for three months. This was later extended to March 1995.

Illegal fishing activities hindered discussions on the cross-border endorsement by Australian authorities during the Joint Technical/Management

Meeting on the Torres Strait Protected Zone. Australia emphasised strongly that it was not going to enter any discussions on cross-border endorsement of beche-de-mer fishing given the illegal fishing by PNG fishermen.

While the Australian Government understands that PNG does not have the capacity for effective surveillance of PNG and the Torres Strait Protected Zone, its representatives gave the impression that PNG was not doing enough to contain PNG fishermen within their legal limits. A letter from the Commonwealth Regional Legal Officer based in Townsville to the Solicitor-General of PNG complained that the ruling by a Magistrate was not acting as an effective deterrent.

Differences such as this may develop and jeopardise the cooperation and understanding that Australia and PNG have in jointly managing the Torres Strait Protected Zone. A similar case in the exploitation of dugong led PNG to complain that it was enforcing management, but Australia was not doing the same. This led to the breakdown in cooperation and possibly over-exploitation.

#### IMPLICATIONS FOR THE BECHE-DE-MER FISHERY

Because of the paucity in the spatial distribution of effort, stocks that are depleted cannot be detected using surplus-yield models without detailed monitoring. If the fishery was monitored through catch and effort, fishermen crossing to the Australian side would be more likely to report the catch as made in PNG. Application of fishery models on the data would be erroneous without complementary information on the behaviour of the fishermen. Lokani (unpublished data) was able to apply the surplus-yield model to some component of the catch data only after verifying the distribution of effort.

The catch-per-unit effort (CPUE) in the fishery for *Parastichopus californicus* in the Washington State beche-de-mer fishery appeared stable, but in reality half in the area fished were over-fished (Bradbury, 1994). This was due in part to the spatial distribution of effort, where fishermen increased effort in deeper areas. Monitoring the behaviour of the fishermen together with an accurate recording of the area fished is important. This would ensure that the distribution of effort is accounted for.

There are provisions for joint management (Haines, 1986) and cross-border endorsement that allow a quota of the yield to be fished by PNG-licensed

boats in the Australian jurisdiction of the Protected Zone and vice versa (e.g. lobster-dive fishery and prawn fishery). Negotiations for such arrangements were jeopardised through illegal fishing activities by PNG fishermen.

#### LEGAL IMPLICATIONS

PNG fishermen apprehended in Australian waters for illegally fishing in the Warrior Reef were prosecuted both in Australia and PNG. In Australia, they were prosecuted for breach of the Torres Strait Fisheries Act and Fishing Industry Organisation and Marketing Act. In PNG, they were prosecuted under the Torres Strait Fisheries Act.

Because the fishermen were apprehended in Australian waters by Australian authorities, prosecution of fishermen in PNG would require arresting officers who were Australian Fisheries Officers. Fortunately, the fishermen prosecuted in PNG pleaded guilty, therefore Australian witnesses were not required.

Rulings for cases heard in PNG on fishing gear were not clear. In any case, Queensland authorities were supposed to have sold by tender all the fishing gear held by them, including the gear for fishermen prosecuted in PNG.

#### COSTING IMPLICATIONS FOR AUSTRALIA AND PNG

Increased patrol and legal costs are expensive. Both Australia and PNG incurred expenses associated with surveillance and prosecution. There was concern by the Australian Fisheries Authorities that the cost of investigating, apprehending and prosecuting illegal fishing in the Warrior Reefs was very high. Given that Australia and PNG have an understanding on surveillance of the Torres Strait Protected Zone with provisions for joint surveillance, it is unnecessarily expensive for Australia to direct its resources to a problem that could be solved by sustaining yields in PNG or by legitimising illegal fishing by endorsement or cross-border fishing.

#### IMPLICATIONS TO THE FISHERMEN

Direct cost implications as a consequence of being apprehended and prosecuted by Australian Authorities are loss of fishing gear and fishing boats, and court fines (if not imprisoned). Closure of the fishery leads to the loss of income to the fishermen estimated at K 1.0 million, while government revenue is estimated to be K150,000 and export revenue to the companies valued at 3.0 million kina annually.





Coastal villagers covered under the Protected Zone are ecologically and economically disadvantaged, and the loss of fishing gear was a big one. The Warrior Reef is the principal area from which the fishermen satisfy their cash and subsistence needs. The loss of fishing gear (including crafts) was very serious indeed. This was displayed by some fishermen who tried to avoid arrest on the reef. A case in point was the incident in which a fisherman assaulted an arresting and escorting officer on the reef, which left him nearly drowned.

#### MANAGEMENT IMPLICATIONS

It is clear that the socio-political objective of the beche-de-mer fishery is important, and may overshadow the economic and biological objectives. The socio-political objective can be addressed directly or indirectly, and has already been addressed directly both by the Australian and PNG authorities. Australia reacted to increased illegal fishing in Australia by stepping up patrols, which resulted in apprehending and prosecuting fishermen in their waters.

Australia also pressured PNG to keep PNG fishermen in PNG waters. PNG reacted by hastily forming a management committee to address management of the beche-de-mer fishery. This resulted in the closure of the fishery in September 1993. The gazetted notice for the closure of the fishery was made under the Fisheries (Torres Strait Protected Zone) (Chapter 210) and Continental Shelf (Living Natural Resources Act [Chapter 210]). The closure was for the period September 1993 to March 1994, and later extended to March 1995.

Fishermen interviewed indicated that the main reason they fished in Australian waters was due to over-exploitation of stocks on the PNG side of the Warrior Reef, and a desire to harvest large sizes of sandfish. Despite their apprehension as early as June 1992, PNG fishermen, continued to cross over to Australia to fish up until the closure of the fishery. Apprehension and prosecution, therefore, did not deter illegal fishing. Fishermen were driven by high prices and a relatively easy and fast way to earn money on a daily basis.

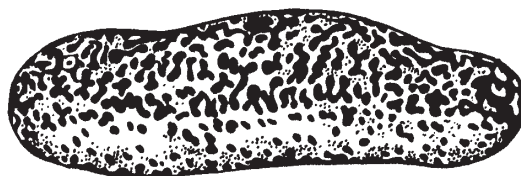
The socio-political objective of preventing illegal fishing and honouring the Torres Strait Treaty could be achieved indirectly by addressing the biological objective instead, without resorting to closing the fishery. This would therefore require sustainable exploitation, which needs to be achieved by conducting studies on the fishery and biology of beche-de-mer species. This has been initiated by the Department of Fisheries and Marine Resources of PNG.

An alternative strategy to stop illegal fishing in Australia is to license Australian fishermen to fish the Australian side of the Warrior Reef. This would effectively reduce the population densities to a level which would make it uneconomical for PNG fishermen to conduct illegal fishing activities in the Australian jurisdiction of the Warrior Reef. Since the cost of labour is very high in Australia an arrangement could be made by having an Australian company own the licence and hiring PNG fishermen to fish for it.

The need for jointly managing the fisheries has not been realised, partly because Australia does not have a recognised fishery for beche-de-mer in the Torres Strait Protected Zone. If the need for joint management arises, then both countries should have effective enforcement. Enforcement of dugong exploitation in PNG was unsuccessful because Australian authorities failed to control Australian based subsistence fishermen (islanders) (Johannes and MacFarlane, 1991).

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## Management of beche-de-mer fisheries in the Western Province of Papua New Guinea

by Paul Lokani<sup>1</sup>, Philip Polon<sup>2</sup> & Ray Lari<sup>2</sup>

### INTRODUCTION

The tropical fisheries for beche-de-mer are centered in the rural coastal areas of the Asia-Pacific region (Conand, 1990). Africa and South America also support fisheries for beche-de-mer. One problem common among all beche-de-mer fisheries is the lack of management and overfishing.

Conand highlighted the need and requirements, both biological and fisheries-related, for the management of beche-de-mer fisheries, which has been elucidated in some parts of the South Pacific (Conand, 1990). The use of this information in the applied management of beche-de-mer fisheries in specific fisheries is limited. This information still need to be updated to suit the specific requirements of the stocks concerned for it to be used effectively in management.

There is currently insufficient knowledge to develop models for rational management of beche-de-mer fisheries (Conand, 1990). Management in Fiji (Adams, 1993), Tonga, Papua New Guinea (Lokani, unpub.) and Queensland lack biological knowledge of the local fisheries and stocks.

These are first steps in management, but they can only be useful if they are evaluated with their respective objectives and improved with the availability of new and updated fisheries and biological information. Banning the use of Scuba gear (e.g. Fiji, Maldives, Papua New Guinea, Tonga) has been justified as enabling the protection of broodstock existing in deeper waters. There is currently no scientific basis to suggest that the so-called broodstock in deeper waters actually produce significant recruits to the population, if at all. However, their existence is reassuring to the managers that something is being done.

The artisanal beche-de-mer fishery in the Western Province of Papua New Guinea needs both biological and fisheries information for it to be managed effectively. Current management of minimum size limit, gear restrictions (which applies to the whole of Papua New Guinea) and a one year closure, is inadequate. Minimum size limits and gear restrictions which were enforced quite effectively, did not

prevent overfishing. Brief descriptions of the fisheries and ecological information form the basis of a management regime which is discussed in this paper. The management regime is being developed and has not yet been enforced.

### FISHERIES

The fisheries for beche-de-mer in Western Province, Papua New Guinea commenced in 1990. Fishing was greatest in the Warrior Reef complex. This was due in part to the limitation in reef growth along the coastline which has been restricted by freshwater run off from the Fly River, swamp lands and numerous streams along the coast. The fishery in Western Province is discussed here in the context of how it occurred and affected stocks in the Warrior Reef system.

Motorised banana boats, averaging 19 feet, made of fibreglass and driven by outboards, were the vessel commonly used by fishermen. Outrigger canoes driven by sail and outboards (Prescott, 1986) were also used. The vessels were used as transport and freight carriers from Daru to the Warrior Reef. Actual fishing involved walking on the reef flat during low tide and snorkelling, while hand collecting sea cucumber into old flour bags. The catch was landed in Daru the same day where it was processed, normally by assistants belonging to the family.

### CATCH COMPOSITION AND CATCH RATES

Sandfish (*Holothuria scabra*) was the targeted species. It formed 100 per cent of the catch in 1990 and 1991, and dropped only because of depleted stocks (Lokani, pers. obs.) [table 1]. Other species harvested were principally of the genus *Actinopyga*. These could not be separated because fishermen identified them by one common name (table 1).

**Table 1: Species composition of the Daru-based beche-de-mer fishery by year (in kg)**

Species	1990	1991	1992	1993
<i>Holothuria scabra</i>	109,380	192,647	159,760	39,302
<i>Actinopyga</i> sp.	0	0	2,937	73,816
Total	109,380	192,647	162,697	113,118

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Increased production of *Actinopygas* species occurred in 1992 and 1993 corresponding to the drop in production of the main species of sandfish (table 1). Similar trends were experienced in the Tigak Islands and Fiji (Preston et al., 1988) where reduction in the high-value species production shifts effort to low-value species.

**Table 2: Mean catch rates (dry weight) per fishing unit from May to August, 1991 (data compiled includes purchase record of 1 trader only)**

Month	mean	n	std. err.	Total weight (kg)
May	10.63	222	1.42	2,361
June	19.14	127	2.82	2,431
July	5.93	95	0.64	564
August	10.80	56	11.96	595

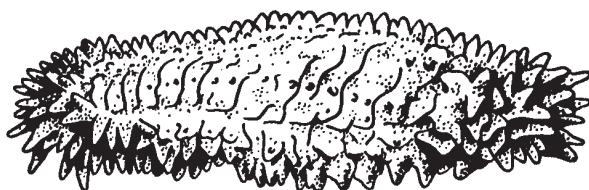
Mean catch rates are based on the sale of products to a single trader ranged from 5 to 11 kg (table 2). Mean catch rate per boat in the Australian jurisdiction of the Warrior Reef by PNG fishermen was 491.66 kg (se=47.42, n=12). This is equivalent to 49.17 kg dry weight. Given the mean number of fishermen per boat was five per banana boat, each fishermen collected 9 kg of product. This catch rate fell within the range recorded in Table 1.

To monitor catch and effort, it is proposed that traders will issue a standard receipt to the fishermen to enable the standard collection of catch-and-effort data when purchasing products.

#### YIELD

Estimated yield per hectare from the fisheries was relatively low when the fisheries commenced in 1990, increasing by almost 100% in 1991 (table 3). By the time the fisheries closed in 1993, yield had dropped to a low of 2 kg per hectare.

Yield estimate from a survey in December 1994 was a slight improvement from the 1993 yield. It is not known if this improvement was due to natural variations of the population or growth and therefore recovery of the population.



**Table 3: Yield estimate for sandfish only, from 1990 to 1994**

Year	Yield (kg/ha)	Source
1990	6	Fishery
1991	11	Fishery
1992	10	Fishery
1993	2	Fishery
1994	3	Fishery

#### BIOLOGY — PRELIMINARY RESULTS

Updating and improving knowledge on the biology and ecology of sandfish in the Warrior Reef for management purposes is the subject of a distribution and abundance, reproduction, growth and movement study which commenced in May 1994. Some of the preliminary analysis (representing data from May 1994 to December 1995) is presented here to support a preliminary management regime.

##### *Distribution and abundance*

In a survey by Lokani and Lari (unpublished), sandfish were found throughout the reef flat, with densities ranging from 0 to 2,562 bdm/hectare. Mean densities at Auwomaza and Wapa were 244 and 136 bdm/hectare respectively. There were no significant differences in densities at Auwomaza and Wapa, but significant differences were apparent for different zones (windward, mid-reef and leeward sites). Populations at both reefs had contagious distributions.

Size distribution at Auwomaza was bi-modal, with a mean size of 18 centimetres while that of Wapa was unimodal, with a mean size of 20 centimetres. The mean sizes at both reefs were relatively small, being good only for C- or D-sized processed products. The small size at both reefs is attributed to overfishing of the large-size products, which were obviously the target of fishermen (Lokani, pers. obs.).

##### *Reproduction*

The reproductive biology of sandfish in the Warrior Reef is being studied by observations and histological processing of the gonad tissue. Histological results are not ready for presentation here. One of the aims of the reproductive study is to determine the spawning season of sandfish.



Graphical display of the gonad index from May to December suggests spawning would occur around the December-to-February period.

At least six species of sea cucumber are known to reproduce asexually, however sandfish are not included in this group. Initial trials to induce fission in sandfish by constriction were successful after at least one week. Growth after two months was at least 2 cm for the anal portion growing the head portion. Proper experimentation of induced fission needs to be carried out.

### **Movement**

Recruitment in sandfish is not known. Patterns of movement may shed light on recruitment patterns. Two movements are possible in sandfish: horizontal movement above the substrate and vertical movement associated with burrowing behaviour.

Mean speed of 12 centimetres per minute was achieved by sandfish. Preliminary analysis of orientation suggests that movement is not random and may be orientated towards specific areas. If this is common, then it may have a bearing on recruitment patterns where settlement is restricted to certain areas of the reef. It was common, for example, to find that where large sizes were common, smaller sizes were very rare.

### **MANAGEMENT**

Management regulations currently exist in the form of size regulations, gear restrictions and permit requirements. These management measures were introduced in response to various resolutions passed by the National Fisheries Councils which called for the management of sedentary resources, of which beche-de-mer was one of the main fisheries. Management measures discussed below only relate to the objective of achieving maximum sustainable yield. A more comprehensive discussion of the management measures are discussed in Anon. (Undated).

### **Size Limit**

The current size limit of 15 centimetres is based on the size at first sexual maturity as calculated by Shelly (1981) for populations at Bootless Bay in Port Moresby. This size limit will be reviewed as soon as the reproductive study is completed. This limit was enforced on the dry products which were inspected by Fisheries Officers at Daru just before export.

Size limit helps to maximise the economics of the fishery, but it depends on proper modelling.

Sandfish are bought according to size, with the larger sizes being more valuable (Conand and Sloan, 1989; Conand, 1990; Lokani and Kubohojam, undated).

### **TAC**

Total Allowable Catch (TAC) equivalent to the maximum-sustainable-yield level is desirable. Initial levels of the TAC will be set at levels to be determined by a simple criteria of:

- 1. TAC will be 90 per cent of the estimated yield.**
- 2. Yield is calculated from 17 cm-plus sizes**

The yield will be determined by visual census using line transects with the precision of the estimate initially set at 20 per cent. The percentage of the yield is initially suggested to offset any underestimate of the yield caused by survey methods and processing methods used.

It has been rightly stated by Conand and Sloan (1989) that diverse social organisations and coastal-area tenure systems make management measures of catch quotas, closures and licencing unrealistic where they exist. The Warrior Reef presents a unique opportunity to apply the catch quota in the form of a TAC together with closures and licensing, because none of the complications highlighted by Conand and Sloan (1989) would affect the fishery. There is a lobster dive fishery in the same reef which has existed since the 1970s.

### **Closure**

Acting on pressure from the Australian authorities over the frequent illegal fishing by PNG fishermen on the Australian side of the Warrior Reef, the Minister for Fisheries imposed a three months closure on the fisheries. This was later extended to a full year until March the following year after a survey revealed that stocks were very low (see Mobiha, undated).

Use of a closed season is seen as an effective strategy to control effort and limit yield to sustainable yield levels. It is anticipated that the closed season will commence when the TAC is reached. Closure during the spawning season is desirable to maximise reproductive output.

Preliminary tests on diurnal movement related to burrowing behaviour suggest that more sea cucumber are exposed during spawning, thus making them more susceptible to fishing. High fertilisation success in *Cucumaria miniata* has been attributed to high population density (Sewell and Levitan,

1992). This has not been investigated in sandfish, but it is appealing that conservative measures are taken. Use of the closed season in China is associated with the spawning period (Conand & Sloan, 1989).

### **Gear restriction**

Enforcement of a ban on underwater-breathing gear is unlikely to have an effect on the stocks of sandfish, as the depth distribution is relatively shallow. The deeper species of white teatfish and prickly redfish may require underwater-breathing gear, but this is unlikely to be attractive to the fishermen at present. Underwater-breathing gear in the form of hookah is currently being used in the lobster fishery on the same reef.

### **Permits and licensing**

A licensing system is proposed for the buyers of beche-de-mer from the fishermen and boats. The number of licences issued to the fishermen will depend on the TAC level. Licences to the buyers will enable them to buy beche-de-mer in Western Province. They will still comply with the current requirements for an export permit for each shipment of export. A requirement of the licence will be issuing of receipts by the buyers.

It is proposed that boats fishing for beche-de-mer from the Warrior Reef will be licensed, with the limit on the size being boats 23-feet in length constructed of fibreglass. The licencing of boats is seen as making surveillance and minimising illegal fishing on the Australia side of the Warrior Reef. Papua New Guinea and Australia have a ratified treaty known as the Torres Strait Treaty, which includes provisions for joint management (e.g. lobster) and cooperation in surveillance activities.

### **Receipts**

A simple log-book system in the form of receipts will be issued by the buyer of products as part of the licence. The receipts will be able to yield catch and effort information of individual fishermen and boats. Buyers need to issue receipts to the fishermen as proof of purchase or trade in any case. The idea of the receipts is to standardise the format and collect additional information on the fishery. By doing so, buyers and fishermen participate in monitoring activities that are there to help the fishery and themselves.

Reliable standard statistics on the fisheries (Conand and Sloan, 1989) are needed to make reliable assessment of the stocks. Conand (1990) could only get

the co-operation of one trader in collecting fishery statistics, possibly because of the competition from other traders.

### **RESEARCH NEEDS**

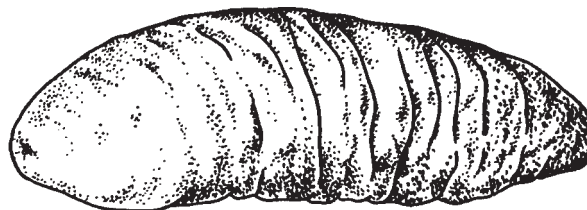
The possibility of enhancing and increasing yield through stock enhancement has not been investigated in sea cucumbers. Teleost fishes and sedentary organisms such as giant clams and trochus have been successfully reared and used for farming or restocking purposes. The three possible stock enhancement techniques that can be investigated are:

- 1. Relocation of recruits,**
- 2. Induced fission,**
- 3. Hatchery rearing.**

Relocation of recruits and young recruits from areas of high abundance to areas of low abundance: This is a simple labour-intensive method that requires study. This study will need to investigate the growth rate at various levels of density. If growth is density-dependent, then the level of density with the highest growth may be taken as the starting density level for relocation. Relocation in the form of sea ranching was recommended by a review of the Maldives beche-de-mer fishery (Joseph, 1992).

Initial trials (Lokani, pers. obs.) on induced fission of sandfish are encouraging. Fission was successfully induced within a week of initial constriction with growth of about 2 cm of the mouth portion within a month. Investigation of induced fission needs to focus on various sizes and the rate of growth for fissiparous products. Similar directions of research for mariculture purposes were said to have been initiated in the Maldives (Reichenbach et al., 1994).

Hatchery rearing is well established in teleost fish, giant clams and trochus. Investigations into rearing sandfish or any other sea cucumber species are probably the best source of recruits for stock enhancement or culture. A cold-water species *Stichopus japonicus* has been successfully reared for stocking or culture purposes (Arakawa, 1990).



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### Current management policies and problems of the inshore fisheries resources in Vanuatu — Sea cucumbers

by Robert A. Jimmy<sup>1</sup>

Sea cucumbers, or beche-de-mer, are seen as one of the major cash crops for many of the remote areas in the South Pacific. In Vanuatu, they are an important source of income locally and nationally. The end products are priced very highly in the South-East Asian Market because they are regarded as a delicacy.

The management of this resource has been very poor, as beche-de-mer harvesting is not a tradition in this country, and also because there has been very little scientific information available on which management can be based. The current legislation in Vanuatu concerning the exploitation of this species is based on a quota system. The Ministerial order of 1991 limits the export of dried beche-de-mer to an annual quota system. So far, records of annual exports of dried beche-de-mer from Vanuatu

have been consistently well below the legal quota (Bell & Amos, 1993). This may mean that the quota could be well above the sustainable level of exploitation for the fishery. The reason for the low production could also be that the resource is not large enough to expand to meet the quota, or there is a lack of enthusiasm by the collectors and exporters to expand.

However, the Fisheries Department needs to conduct resource assessment surveys in order to determine appropriate exploitable levels of the stock available. Chambers (1989) recommended that the correct strategy with regard to beche-de-mer harvesting in Vanuatu would be to collect intermittently from sites which are large enough and support sufficient densities of commercial species in order for it them be economical.

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Since no legislation has been effective in controlling the exploitation of this resource, Fisheries Enforcement Officers have so far based their actions on their individual judgement and experience in the field. This approach leads to inconsistency, as there are no written rules on which to base prosecutions. In addition, problems arose when there was a national strike and new employees recruited — it is difficult for them to recognise undersized dried beche-de-mer. Beche-de-mer exporters could export undersized animals, knowing that they could not be prosecuted because there was no legislation by which Fisheries Officers could secure convictions.

Export data are usually given to the Fisheries Department, indicating tonnage collected per given area. However, these do not show which species are more heavily exploited than the others. Fisheries Officers realised that it might not be absolutely necessary to adopt legislation from other member countries, because environmental conditions influ-

encing the growth and survival of sea cucumbers might vary between countries. In addition, concern is also being raised over differences in shrinkage among species, which would of course have an effect on the size limit of the processed animals. It might be necessary to have processing trials on various commercial species to be able to come up with size limits for different species. This could include legislation covering species of commercial importance.

The quality of dried beche-de-mer in the country must also be effectively controlled when competing with the rest of the market in the region. In Vanuatu, especially in the areas where beche-de-mer fishing is most popular, the only means of transport is by boat. And since the sun-dried method is the only method used for processing this resource, organisms such as fungus tend to infest the processed animals, making them unsuitable for sale. In one case, 3.5 tonnes of sun dried beche-de-mer had to be discharged due to fungal infection.

### Status and management of inshore fisheries in the Kingdom of Tonga: Beche-de-mer

*by Ministry of Fisheries*

The fishery began in Tonga in the early 1980s. It is based in the Ha'apai island group with its abundant coral reefs, although product is also harvested from the Vava'u and Tongatapu island groups. The fishery began to develop rapidly after the introduction of assisted underwater breathing apparatus (scuba and hookah) in the late 1980s–early 1990s. Despite an absence of recorded data, it is likely that the fishery peaked in 1994.

After fishers collect the sea cucumbers, they either clean and process them themselves before selling to an exporter, or they sell them fresh to either a middleman or direct to an exporter who cleans and processes them. Generally the fisher is paid between T\$5 and T\$7 [1 T\$ = US\$ 0.75] per plastic bucket for sea cucumbers, regardless of species composition. On occasion, the fisher is paid in the way he prefers—using a sliding fee per animal, depending on the species and size. There are ten registered exporters in Tonga, seven of whom are active.

The Beche-de-mer fishery in Tonga is attractive to fishers, as the animals are easy to collect, dried product keeps without ice, and there is always a market. These features, combined with the 'open-access nature' of Tongan fisheries, are causing a rapid demise in the stocks of sea cucumbers in

Tongan waters. As higher-valued species are becoming less abundant, lower-valued species are being harvested in increasing amounts. Information from the Ministry of Fisheries seven-month-old export fisheries database has supported this observation. This information includes the following:

- ☞ Higher value sea cucumbers are not being collected in increasing amounts. For example, sandfish free-on-board (FOB) value is T\$25.00 but exports have remained static and average 116 kg/month;
- ☞ Higher prices are being paid for less popular species. For example, elephant fish were T\$2.00/kg FOB in November, but now fetch T\$7.00 FOB;
- ☞ The quantities of lower-valued species exported has increased. For example, greenfish was not exported until January 1995 (334 kg), yet by March, 13,025 kg was exported;
- ☞ Despite either stable or increased prices, regularly increasing production has occurred in only three of the 15 species traded, and there are species fetching T\$7.00 or less FOB prices;

- ☞ Larger and/or more valuable sea cucumbers are now coming from waters either only accessible to scuba and hookah divers (i.e. stocks within free diving and reef-walking limits are fished out) or from previously unfished areas, or both;
- ☞ Smaller and smaller pieces of dried product are being exported. A one kg bag of dried greenfish recently exported contained an estimated 350 pieces;
- ☞ Even though the price fishers receive is very small compared to the value of the dried product, there are reports of fishers earning enough from sales to build their own homes. Such rewards must represent many tonnes of fresh product per family. Six fishers selling their product to a middleman in Talu, Vava'u group, harvested 55,776 surf redfish (telehea) over the four-month period January to April this year (i.e. 2,324 telehea/man/month).
- ☞ Changing market preferences, coupled with a decline in stocks of many species, has meant that species traditionally used in the subsistence diet (e.g. for lomua) are being harvested.

#### MANAGEMENT PLANS

The major ones are:

- ☞ a widespread public awareness campaign, particularly directed at fishing communities;
- ☞ strict implementation of the fisheries regulations by the Ministry of Fisheries, pertaining to sizes for both the fresh and dried form (legal minimum sizes have been declared for some species already);
- ☞ nomination of minimum sizes for unregulated species;
- ☞ a restriction on the number of exporters to ten, with no additional licences offered;
- ☞ immediate ban on the use of scuba and hookah gear for collecting sea cucumbers, and effective policing of the ban;
- ☞ spot surveys in areas previously (1984, 1990) surveyed, to allow an assessment of the extent of the harvesting and to permit nomination of quotas.

Supporting management measures are: encouraging community management; designating a beche-

de-mer liaison officer; schedule a closed season at the end of each year (when most species are spawning); nominate and police closed areas; conduct an economic survey into the fishery; carry out research on wet-weight/dry-weight conversions, biology, and appropriateness of measurements; undertake aquaculture studies on inducing fission in local species; and teach better handling and processing procedures in communities.

**Table 1: Total recorded exports of beche-de-mer from 1990 to November 1994 (source: Customs Department) and for 1995 (Source: Ministry of Fisheries)**

Year	Quantity (kg)	Value (T\$)
1990	no record	no record
1991	9,767	47,978
1992	no record	no record
1993	35,367	427,745
1994	61,449	805,816
1995 (5 mths)	60,160	515,305

**Table 2: Information on exports of product by species from November 1994 to end of May 1995)**

Species	Total exports (kg)
Sandfish	2,089
Surf redfish	23,385
Stonefish	7,554
Black teatfish	2,976
White teatfish	6,650
Greenfish	17,931
Tiger/leopardfish	1,194
Prickly redfish	1,300
Curryfish	5,400
Brown sandfish	680
Blackfish	760
Lolly fish	19,295
Black lollyfish	672
Elephant's trunk fish	1,345
Black sandfish	980
(unstated)	1,030



## Statistics on beche-de-mer exports

Compiled by Chantal Conand and the SPC  
Fisheries Information Section

We have collected statistics from various sources, countries and territories. Figures are presented for the following countries and territories: New Caledonia, Tuvalu, Solomon Islands, Papua New Guinea, and Tonga. We hope to be able to present a regular statistical column in this bulletin in the future.

### 1. BECHE-DE-MER EXPORTS FROM NEW CALEDONIA (KG) (SOURCE: CHANTAL CONAND)

Destination	1990	1991	1992	1993	1994
Hong Kong	122,678	119,900	76,510	37,452	66,878
Singapore	0	0	0	0	8,400
Others	3,920	3,700	3,715	2,022	4,587
Total	126,598	123,600	80,225	39,474	79,865

### 2. TUVALU BECHE-DE-MER EXPORTS (SOURCE: SAMUALU LALONI, FISHERIES RESEARCH OFFICER)

In addition to the questionnaire, I have been able to interview some people who worked for the two exporters, and they all agree that numbers of beche-de-mer are decreasing. They tend to see fewer and fewer beche-de-mer in one area after a few months. Also they tend to spend longer periods of time diving to get numbers they would normally get with lesser effort.

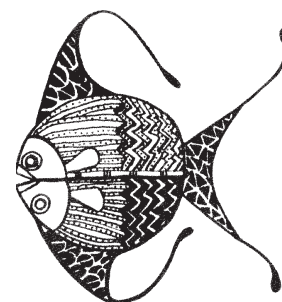
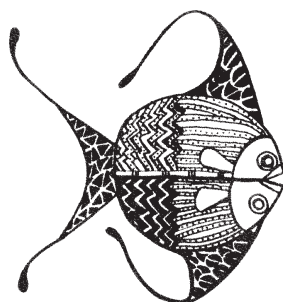
The following beche-de-mer species are exported by the two exporters: white teatfish, leopard tiger fish, prickly red fish, elephant's trunk fish, black fish, surf redfish, black teatfish and brown sandfish.

In 1993, only one exporter was operating at the time, and a total of 895.35 kg of beche-de-mer were exported. In 1994, two exporters were operating and between them 3,697.45 kg of beche-de-mer were exported. In 1995 the same exporters exported 3,217.75 kg of beche-de-mer.

At present the two exporters are not operating as actively as in the past. This is mainly because of a couple of fatal diving accidents that have resulted from the improper use of hookah gear. Also, divers without diving gear are reluctant to dive in deeper waters as the resource in shallower waters becomes depleted.

### 3. SOLOMON ISLANDS EXPORTS FOR 1995 (SOURCE: FISHERIES DIVISION)

Month	Quantity (kg)	Value (SI\$)
January	—	—
February	7,189.5	106,790.4
March	—	—
April	7,652.5	125,405.9
May	4,260.0	23,000.0
June	1,181.4	13,471.7
July	17,855.0	139,601.8



#### 4. PAPUA NEW GUINEA EXPORTS (SOURCE: BARRY D. KARE, SENIOR FISHERIES BIOLOGIST, NATIONAL FISHERIES AUTHORITY)

New trends have emerged from the renewed interest in exploitation of beche-de-mer in PNG. As species of higher commercial value have been over-harvested, fishermen have resorted to targeting less valuable species, such as deep-water redfish (*Actinopyga echinites*). Localised over-exploitation of beche-de-mer has been experienced in several locations, for example in the Western Province.

This fishery (Western Province) was closed in September 1993 for a year. Biological research was conducted during this period by an officer of National Fisheries Authority (NFA), currently studying for his Masters Degree at James Cook University. His initial findings were that the fishery was recovering at a very slow rate. Based on his

findings, a comprehensive Management Plan has been put in place and this will be implemented when the fishery opens sometime this year. Among other measures, the plan includes total allowable catch, time closures, licencing of exporters/buyers etc. Management plans for other fisheries are yet to be completed, for example Tigak fishery in the New Ireland province.

Export statistics are detailed below for the past three years and the first six months of 1995. Unfortunately, the records kept by our Export Branch are not kept species by species, so the data is a combination of species exploited in PNG. These species include, *Holothuria scabra*, *H. nobilis*, *H. fuscogilva*, *Thelenota ananas*, *Actinopyga miliaris*, *A. echinites* and *H. fuscopunctata*.

Month	Quantity (kg)	Value (Kina)
1992	419,452.30	3,409,738.71
1993	499,849.46	3,044,843.85
1994	207,111.23	1,845,061.29
1995*	122,788.51	1,199,649.23

For currency comparisons, K1 is approx. equal to A\$ 0.9663; this is after the devaluation of Kina in June/July 1995. The value of Kina to Australian Dollars before the devaluation was approx. A\$1.40.

#### Beche-de-mer fishery in Baja California

by German Perez-Plasencia

An artisanal sea cucumber fishery started work only recently in Baja California (Mexico) thus there is a great lack of adequate biological information and statistics of the captures about the only two species known to be harvested (see figure on page 14).

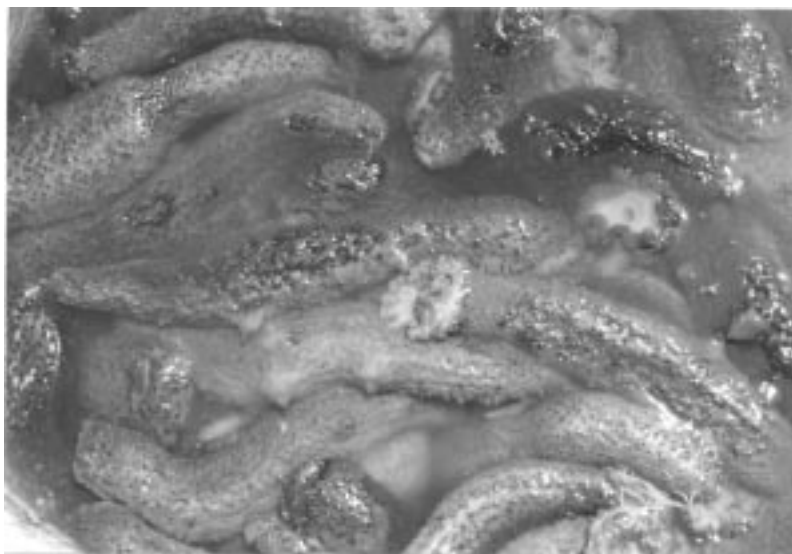
A small fishery started around 1988 in the Baja California State, first in the Gulf of California region with *Isostichopus fuscus*, and in 1989 there were already landings reported for the Pacific littoral, where *Parastichopus parvimensis* was the species harvested.

The table shows the annual landings for the North-east Pacific region in Baja California, expressed as total wet weight (tonnes) of the organisms, but it is highly probable that not all the captures were reported.

The price for the unprocessed sea cucumber (fresh wet weight) is US\$0.80/kg, which is not very at-

Year	Production (tonnes)
1989	52.0
1990	189.2
1991	662.0
1992	729.4
1993	367.0
1994	563.1

tractive for fishermen compared to the sea-urchin gonad that reaches up to US\$38.00/kg. The sea-cucumber fishery serves then as an alternative when the sea-urchin season is closed. All of the sea-cucumber production in Baja California is processed (body wall, muscular bands or whole clean body) for the Japanese market, but like its closer relative *P. californicus*, the market for *P. parvimensis* is not well developed and is unstable.



Close-up of *Parastichopus parvimensis* [Photo: G. Perez]

The fishermen dive using air-compressors and there are no records of capture and fishing effort (number of sea cucumbers collected per diver, number of divers, total diving time, number of landing boats, zones of capture, etc.). That is the reason why no estimation of the CPUE has been made, but it is clear that the volume of capture decreased after 1992 (see table).

The fishery of *I. fuscus* and *P. parvimensis* is controlled by the Department of Fisheries (Departamento de Pesca (PESCA) in the State of Baja California, but no area restrictions or harvesting seasons exist at the moment. Estimations of the exploited stocks have also not been made yet.

The Facultad de Ciencias Marinas at the Universidad Autonoma de Baja California has studied the biology of *Parastichopus parvimensis* regarding its biometry, reproduction and growth, as well as aspects related to its pharmacological properties. This constitutes the first formal research on this species in the region.



Processing plant in Ensenada, Mexico [Photo: G. Perez]

## Commercial holothurians in South Sulawesi, Indonesia: Fisheries and mariculture

by Chantal Conand<sup>1</sup> & Ambo Tuwo<sup>2</sup>

### INTRODUCTION

Indonesia is probably the first producer-country worldwide for teripang or beche-de-mer (Conand, 1989, 1990; Tuwo and Conand, 1992; Conand and Byrne, 1993). Little is known about its artisanal fisheries, but overexploitation is occurring in South Sulawesi (Erdmann, 1995). Concern for a rational management of these coastal resources is presently increasing (Hanafi and Suryati, 1994), as for other marine organisms.

We present here a few observations on the teripang fishery from Barrang Lompo, a small island of the Spermonde Archipelago, and on growth trials at Kambuno Island, South Sulawesi.

### THE FISHERY

As in the other producing countries, there are at least five levels within the holothurian fishery where statistics may be collected (Conand and Byrne, 1993). This study presents preliminary observations on holothurian species and quantities processed from sampling by processor-fishermen and collectors.

In Barrang Lompo, around 300 fishermen on 30 boats go away for long periods and collect sea cucumbers from lagoons and reefs far away in areas such as Maluku, Timor and North Australia (Erdmann, 1995). They are not used to processing their catch on board, and keep it in salt after slitting and evisceration (Tuwo and Conand, 1992). It is, therefore, difficult to identify the species accurately.

In December 1995, a few visits to the processors (there are about 60) have allowed us to establish a list of the species fished (Tuwo and Conand, in press). It has appeared unrealistic to sample before processing, because the different species of sea cucumber are mixed together in salt and kept in the shade of the ground-floor of the traditional house.



Figure 1A: Smoking *Thelenota ananas*  
[Photo: C. Conand]

During the phases of boiling and smoking, the species are identified more easily (figure 1A), yet during sun-drying is the most appropriate phase for sampling (see figure 1B on page 19).

Table 1 shows the quantities, size intervals and medium size of the sorted species, sampled by processors and a chinese collector. More than ten species of sea cucumbers have been observed, but the taxonomy has yet to be checked. To establish the capture totals in fresh weight, the shrinkage rates during processing and the length-weight rela-

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Table 1: Results from the sampling at Barrang Lompo

Date and sampling site	Species	Quantity	Size interval (cm)	Medium size (cm)
9/12/95 Collector (sun-drying)	<i>Actinopyga</i> sp.	1,000	10–14	12
	<i>Actinopyga</i> sp.	100	<10	–
	<i>H. fuscogilva</i>	25	18–20	19
	<i>H. coluber</i>	2	20	20
	<i>H. fuscopunctata</i>	–	–	–
	<i>Stichopus</i> sp.	1,000	3–10	7
	<i>Thelenota ananas</i>	8	20–26	24
	<i>Thelenota ananas</i>	2	<10	–
	<i>T. anax</i>	30	30–35	32
	<i>T. anax</i>	4	<12	–
25/12/95 Collector (sun-drying)	<i>Actinopyga</i> sp.	1,150	6–15	12
15/12/95 Processor (sun-drying)	<i>Bohadschia vitiensis</i>	–	–	16
	<i>H. scabra</i> var. <i>versicolor</i>	210	7–20	13
	<i>T. anax</i>	30	–	30
16/12/95 Processor (sun-drying)	<i>T. ananas</i>	1	–	25
	<i>T. anax</i>	96	20–34	24
	<i>T. anax</i>	3	11–13	–
25/12/95 Processor (sun-drying)	<i>T. ananas</i>	3	18–22	–
	<i>T. anax</i>	146	22–33	24

tionships established for the different species (Conand, 1989, 1990) have been used. It has been postulated that the shrinkage rate of *Thelenota ananas* could be used for *T. anax*. (a study should be undertaken to check this point).

A few species have not been sampled (see table 1, *H. fuscopunctata* for example, which has frequently been seen in salt before boiling) and sampling might also not have included all processing or drying sites on the island. The results, presented in table 2, are thus probably underestimates.

Some comments can be made about these observations. From the evaluation of the total captures, the drying and dried products are not the same during successive weeks, indicating a rapid turnover; this point will need further investigation at the fisherman, processor and collector levels.

With minimum estimated captures around 1,000 kg, the product dried should be at least 100 kg each week. It also appears that two species are largely predominant: *Actinopyga* sp. and *Thelenota anax*.

The first has only been observed by the collector (who might have made stocks); the second has been seen by all processors, indicating that it is a target species despite its very low commercial value (the fishermen get a price 10 to 15 times less than for the teatfish, *H. fuscogilva*, a valuable but rare species).

Small specimens are also collected by fishermen, showing that they presently harvest all the holothurian species that are still available—even illegally, as 25 boats were confiscated in Australia (Erdmann, 1995).





Figure 1B: Sun-drying *Thelenota ananas* [Photo: C. Conand]

Table 2: Captures evaluated from the sampling (TL = total length)

Species		Size category			Captures (kg)		
		TL dry (cm)	TL fresh (cm)	Weight (g)	9/12/95	16/12/95	25/12/95
<i>Actinopyga</i> sp.	large	12	26	650	650.0	—	750.0
	small	7	15	140	14.0	—	—
<i>H. fuscogilva</i>		19	43	2,100	52.0	—	—
<i>H. scabra versicolor</i>		13	34	1,250	—	262.0	—
<i>Stichopus</i> sp.		7	20	250	250.0	—	—
<i>Thelenota ananas</i>	large	24	60	4,200	34.0	4.0	8.0
	small	8	21	400	—	—	—
<i>T. anax</i>	large	30	80	5,500	165.0	165.0	—
	medium	24	62	2,600	—	250.0	380.0
	small	10	25	200	0.8	0.6	—
Captures					1,165.8	681.6	1,138.0

## GROWTH TRIALS

Growth trials in cages have been undertaken to offer an alternative to sea-cucumber fishermen. These growth trials (figure 1C) are presently in progress at Kambuno Island, near Sinjai, in a site protected from the waves. The sandy muddy substrate (water depth is 50 cm at low tide) is covered by sea grasses.

The cage (25 x 25 m) is made of net, with a mesh size of 0.5 cm, deeply buried in the sediment to avoid holothurian escape. Young specimens of the sandfish *Holothuria scabra* (figure 1D), around 10 cm of total length, are collected at low tide on a nearby estuary flat.

Preliminary data showing a relatively rapid growth after three months will be presented in the next issue of the Beche-de-mer Information Bulletin.

## CONCLUSION

This preliminary study by sampling during the processing on one island of Southwest Sulawesi has shown that the exploitation of sea cucumbers is very intense and raises many problems. Such enquiries should be undertaken on a regular basis, for teripang processors and collectors, at least in Barrang Lompo Island.

They will enable us, through case studies, to follow the trends of the captures of different species. Sampling during fishing, or enquiries by fishermen are



Figure 1D: Young *Holothuria scabra* put in enclosures [Photo: A. Tuwo]

also needed to correlate the captures with the fishing effort.

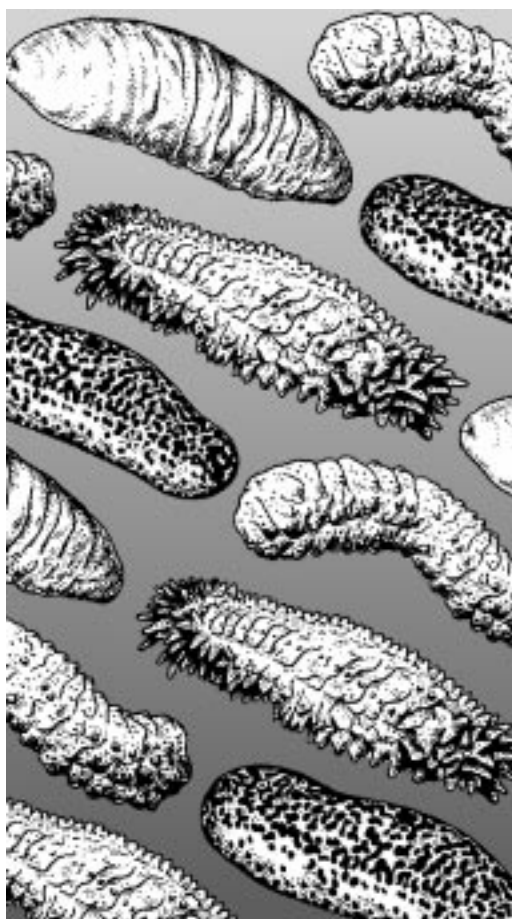
Thereafter, variations in the sizes of the product and the catch-per-unit effort will permit better understanding of these overexploited resources. Mariculture projects also look promising to increase the resource.



Figure 1C: Enclosures for growing sandfish [Photo: A. Tuwo]

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# STUDIES ON THE REPRODUCTIVE BIOLOGY OF THE ATLANTIC SEA CUCUMBER *CUCUMARIA FRONDOSA*

## Gonad morphology and gametogenesis of the sea cucumber *Cucumaria frondosa*

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### Abstract

The occurrence of a particular gonad morphology, with distinctive large tubules and smaller, less-mature ones, was investigated in sea cucumber *Cucumaria frondosa* throughout the north-east American coast. Observed in individuals from high latitudes, this characteristic was not present in populations south of New Brunswick. Monitoring of the reproductive cycle in *C. frondosa* from the Lower St Lawrence Estuary, eastern Canada, showed that gametogenesis was initiated in early winter, after the first increase of day length, and coincided with a transfer of energy from the body wall to the gonad. The subsequent increase of gamete synthesis, in early spring, related to the abundance of food and the rising temperature. The early summer spawning was characterised by a significant decrease in the gonadal tubule size, index and calorific value.

### INTRODUCTION

Knowledge of the gonad morphology of sea cucumbers is crucial to the understanding of their reproductive cycle. It was recently realised that the often confusing information given in early studies of the sea cucumber *Cucumaria frondosa* (Jordan, 1972; Coady, 1973) stemmed from an imprecision regarding size disparity among the gonadal tubules. It therefore remains a question whether or not it could have made a difference in the proposed description of the reproductive cycle.

Now we know that while some holothurians possess a single type of gonadal tubules which all undergo an entire gametogenetic cycle in one year (Tanaka, 1958; Costelloe, 1985, 1988; Sewell & Bergquist, 1990), others demonstrate a more complex gonadal development, occurring in tubules of variable size and degrees of maturity (Smiley & Cloney, 1985; Smiley, 1988; Smiley et al., 1991; Tuwo & Conand, 1992; Hamel et al., 1993). In those cases, only a fraction of the gonad becomes mature during the spawning season.

Further, it appears that the presence of different sizes of tubules in the gonad is not always a constant feature in a given species. Gonad morphology can vary according to geographical location, as demonstrated by Sewell (1992) for *Stichopus mollis*. For that reason an extensive sampling over a wide range of latitudes was conducted during our study in order to demonstrate this phenomenon in

*Cucumaria frondosa*. Focusing on the St Lawrence population, we then thoroughly monitored the gametogenetic cycle in small and large tubules, in relation to environmental factors.

### MATERIAL AND METHODS

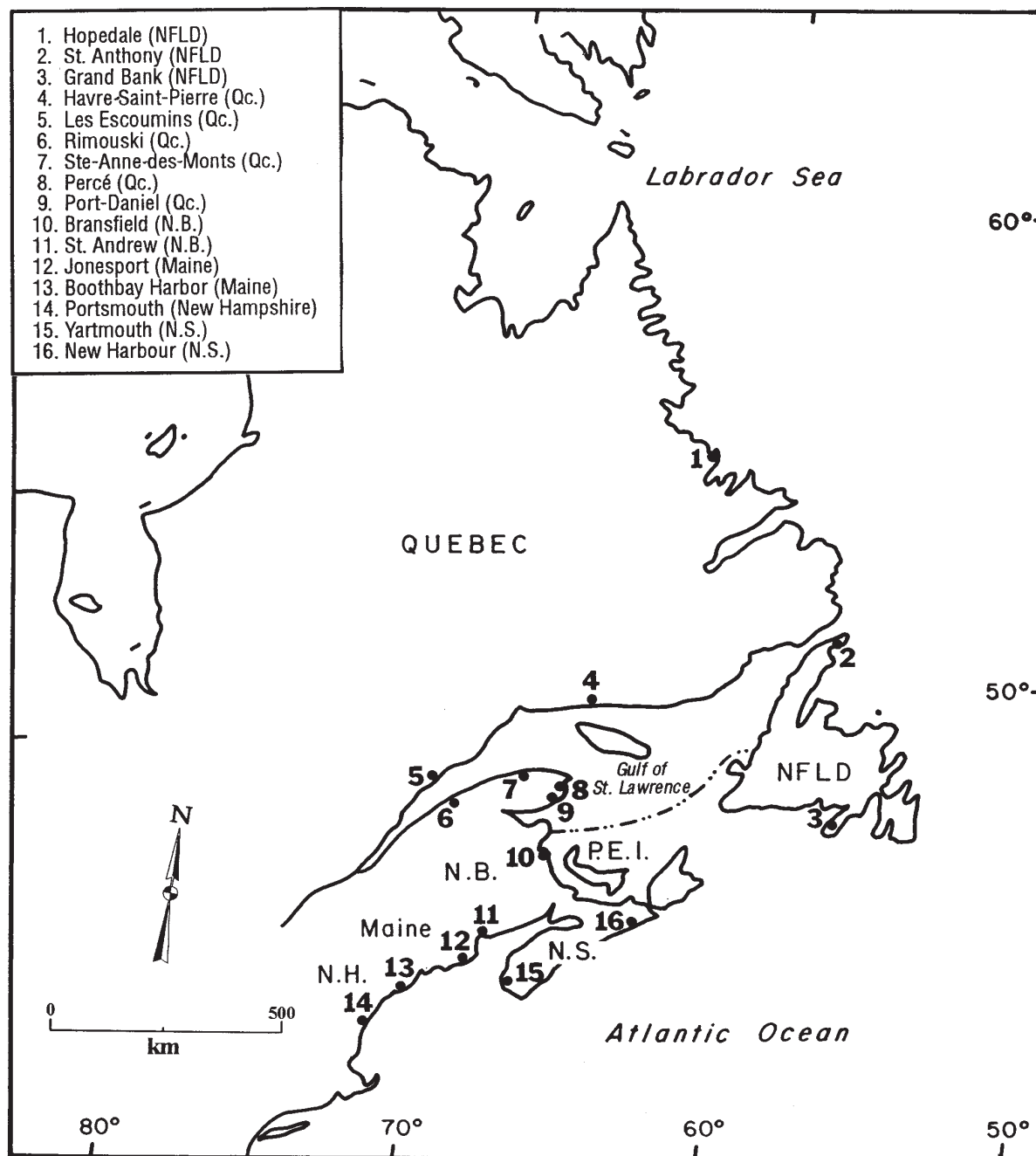
#### Gonad morphology under different latitudes

This protocol was designed to verify the occurrence of two classes of gonadal tubules in different populations of *Cucumaria frondosa*. Individuals (about 40 males and 40 females) were collected during spring (before spawning) between 1987 and 1993.

Collections were made in 16 different locations scattered along the east coast of Canada and the United States. The sea cucumbers were collected by dredging or Scuba in the following stations (figure 1):

- Station 1: Hopedale at about 20 m depth;
- Station 2: St. Anthony at 15 m depth;
- Station 3: Grand Bank at 12 m depth;
- Station 4: Havre-Saint-Pierre at 3, 13, 25 and 52m depths;
- Station 5: Les Escoumins at 5, 10, 20, 40 and 60m depths;
- Station 6: Rimouski at 110 m depth;

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**Figure 1:** Map of the north-east American coast showing the 16 sampling sites where we studied the gonad morphology. The interrupted line located between stations 2 and 3 indicates the limit between *Cucumaria frondosa* with 2 size classes of gonadal tubules (upper limit) and those with one class of gonadal tubules (lower limit).

- Station 7: Sainte-Anne-des-Monts at 15, 30 and 120 m depths;
- Station 8: Percé at 15 m depth;
- Station 9: Port-Daniel at 20 m depth;
- Station 10: Bransfield at 20 m depth;
- Station 11: St Andrews at 3 and 90 m depths;
- Station 12: Jonesport at 15 m depth;
- Station 13: Boothbay Harbor at 10 m depth;
- Station 14: the Islands of Shoal in front of Portsmouth at 20 m depth;
- Station 15: Yarmouth at 20 m depth; and
- Station 16: New Harbour at 15 m depth.



All individuals were dissected and visually inspected for the presence of two classes of gonadal tubules.

### ***Reproductive cycle of *Cucumaria frondosa* from the St Lawrence Estuary***

#### *Collection of individuals and histological procedures*

Male and female *Cucumaria frondosa* were periodically collected at Les Escoumins on the north shore of the Lower St Lawrence Estuary, eastern Canada (48° 21' N : 68° 47' W) from April 1992 to November 1993. They were dredged from a depth of about 20m, usually every month and exceptionally bi-monthly when the spawning period was anticipated. The dissections and subsequent mass records all involved fresh animals.

During histological procedures, freshly collected gonads were transferred to Bouin's fixative for four weeks and then processed according to standard embedding and coloration techniques (Hamel et al., 1993). Five longitudinal cuts were made across the tubule and stained with Periodic acid-Schiff (PAS). When applicable, separate examinations were made on small (<2.2 mm in diameter) and large (>2.2 mm) gonadal tubules. Those two classes of tubules were established using the parameters in Hamel et al. (1993).

#### *Gametogenesis*

The stage of gonadal development associated with the population at each sampling date was determined in 15 males and 15 females, using the previously described histological techniques. The five gonadal stages (post-spawning, recovery, growth, advanced growth and maturity) were defined in the recent study of *Psolus fabricii* (Hamel et al. 1993). This sea cucumber shows a close anatomical resemblance to *Cucumaria frondosa*, and also presents a very similar reproductive cycle. We also measured the tubule diameters under a microscope.

#### *Determination of body component indices*

The wet mass of the body wall, without the aquapharyngeal bulb and the muscle bands, was chosen as a denominator to establish the different tissue indices. The intestine (together with its contents) was removed from the posterior end of the stomach to the beginning of the cloaca, the gonad from its point of attachment to the gonoduct, and the respiratory tree from its point of attachment to the cloaca. The muscle bands of the body-wall and those of the aquapharyngeal bulb and cloaca were removed from the body wall last. All indices were

calculated as the ratio of dry organ mass to wet body-wall mass. For each collection date, the various indices were measured in 15 males and 15 females, ranging from 270 to 320 mm distance mouth to anus, previously determined to show minimum inter-individual variations. We established the ratio between mature males and females collected at each sampling date.

#### *Energy content in the tissues*

The seasonal fluctuations of energy content in all major organs were measured to give a more complete portrait of the reproductive cycle. We determined the calorific value of the gonad, the intestine including its content, the respiratory tree, the muscle bands and the body wall in 15 males and 15 females, at each sampling date. In the case of gonads, small and large tubules were considered separately. Routinely, the organ samples were dried to constant mass at 55°C in an oven. The material was then grounded to a fine powder and mixed carefully. The caloric content was evaluated by calorimetry (Parr macro oxygen bomb calorimeter), in three samples ( $\approx 1$ g dry mass) of the same organ. These calorimetric measurements provided a quantitative estimate of the total amount of energy present per unit of material combusted. These data in  $\text{calory.g}^{-1}$  ash free dry mass were transformed into  $\text{kJ.g}^{-1}$  dry mass.

#### *Seasonal variation of the environmental factors*

The chlorophyll a concentration was recorded weekly at the study site by collecting three water samples (8 l) at 15 m depth, during high tide (Hamel & Mercier, 1995). The temperature at 15m was recorded by three Peabody Ryan thermographs. The data of day lengths were obtained from the weather station at the Quebec Airport (Environment Canada, Atmospheric Environment Service). Data of fresh-water run-off, combining four rivers—Montmorency, Batiscan, Sainte-Anne and Chaudière—were provided by Environment Canada (Climatologic Services).

#### *Size at sexual maturity*

To establish the growth pattern of the gonads, and the size at sexual maturity, 567 individuals of all sizes, from 1 to 350 mm (distance mouth-anus), were collected in April 1992, a few weeks before the anticipated spawning period. The gonads of individuals over 100 g were inspected under a binocular, while histological procedures were used to determine the degree of maturity in smaller individuals. Sea cucumbers were classified as adults when bearing mature gametes, as immature when

bearing gametes in the early stage of development, and as non-differentiated when no gametes were present. The gonadal index was measured according to the previously described method. We also evaluated the total amount of mature oocytes (fecundity), as well as the number of gonadal tubules and their length in all-sized individuals.

## RESULTS

### Gonad morphology

The gonads of sea cucumbers collected from the highest latitudes (Labrador coast, station 1) down to the Chaleur Bay (Quebec, station 9), including station 2 on the north shore of Newfoundland, were divided in two classes of gonadal tubules (see figure 1). The sea cucumbers collected from the east coast of New Brunswick (station 10) down south to the Shoals Islands (New Hampshire), including station 3 in Newfoundland, did not present the distinctive classes of tubules observed in the north. All their gonadal tubules were in the same stage of development, roughly had the same diameter and attained maturity after a single year.

In St Andrews (station 11), Saint-Anne-des-Monts (station 6), Les Escoumins (station 5) and Havre-Saint-Pierre (station 4) sea cucumbers were collected at different depths. There was no difference in the gonad morphology at each of those depths. When two classes of gonadal tubules were observed in shallow water (<20 m), they were also present at greater depths.

### The St Lawrence Estuary population

The gonad of adult *Cucumaria frondosa* from Les Escoumins was divided into numerous gonadal tubules (120 to 140 tubules.ind<sup>-1</sup>), each measuring about 160±10 mm in length. Advanced gametic stages (advanced growth and maturity) predominated in the large tubules, and earlier stages (post-spawning, recovery and growth) in the small tubules (see figure 2).

The small tubules (<2.2 mm in diameter) were those undergoing their first year of growth, and the large tubules (>2.2 mm in diameter) those attaining their maturity and involved in the spawning of the current year. During this study, all individuals observed had an approximately equal number of small and large tubules at any time.

Gamete development occurred uniformly all along the germinal epithelium, except in the first centimetre, near the gonoduct, which was empty of gametes, very constricted, and showed a smaller diameter and an atrophied germinal epithelium.

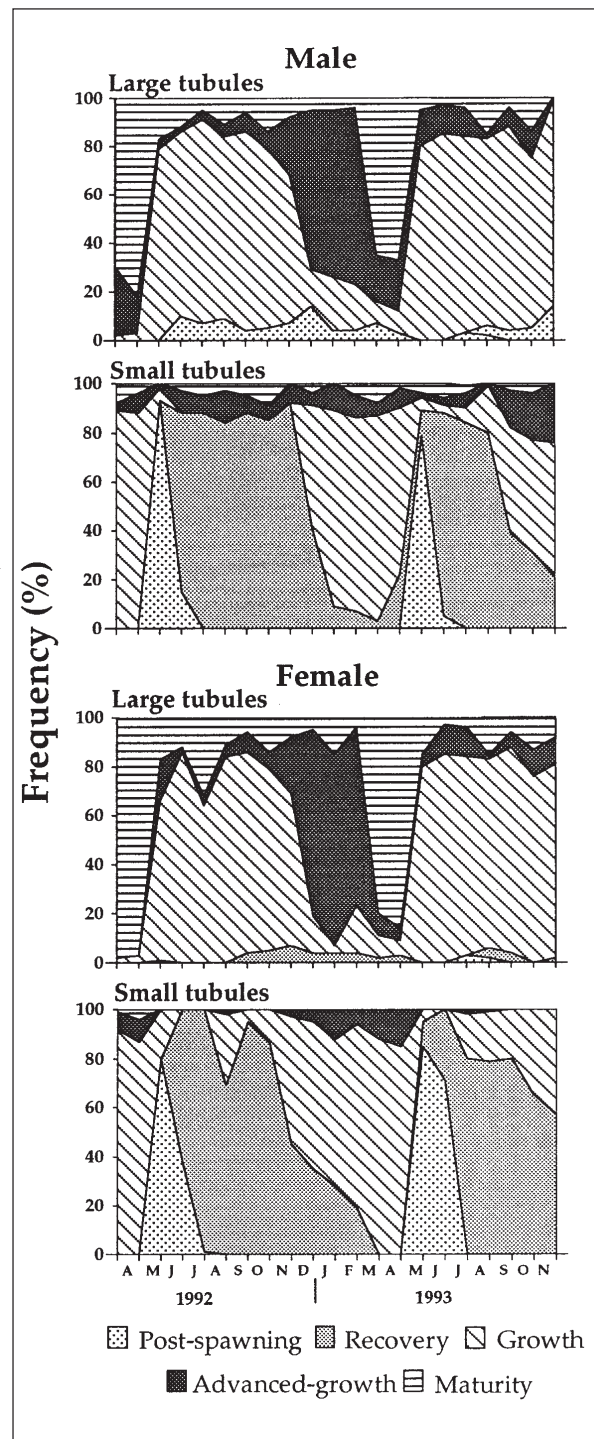


Figure 2: *Cucumaria frondosa*. Relative frequency of different gametogenetic stages in small and large tubules of males and females from April 1992 to November 1993.

All gonadal tubules were joined to a single gonoduct leading to a gonopore located between the tentacles.

No significant departure from a sex ratio of 1:1 was observed in any of the samples, and the ratio of the pooled samples was 512 males for 542 females ( $\chi^2_{0.05}$ , 14,  $p > 0.05$ ).

### Size at sexual maturity

Gonadal tubules were present in all individuals with a body-wall mass superior to  $\approx 1$  g. Histological preparations revealed that only undifferentiated precursor cells were present along the germinal epithelium of individuals with a mass under 40 to 42 g, making it impossible to recognise males from females.

The non-differentiated gonads had a uniformly cream colour. The individuals only became sexually distinct (still immature) when reaching 42 to 50 g (see figure 3), at which time histological investigations allowed us to observe many precursors of mature sexual cells, especially along the germinal epithelium. Numerous nests of oogonia, or long and thin layers of spermatogonia, were then observable.

The testis and ovary indices remained comparable up to a body wall mass of 45 to 60 g (see figure 3). Upon reaching that size, males and females at-

tained their sexual maturity and their gonads developed a clear sexual dimorphism; the male gonad becoming light pink and that of the female presented a dark-red colour.

Maturity was confirmed by observation of the first oocytes with PAS-positive yolky reserve and the first few spermatozoa. The relative value of the gonad indices increased sharply as the body-wall mass rose from 47 to 60 g, especially for males (see figure 3). At that time, there were not many mature gametes in the gonad, as they represented less than 5 per cent of the oocytes and less than 8 per cent of the sperm cells.

From that size on, the gonadal index of males was always higher than that of the females, with a minimum of overlapping. Individuals with a body-wall mass between 120 and 180 g showed the smallest variations due to body size (see figure 3) and were therefore used for monitoring the gonadal index and other tissue indices in all experiments.

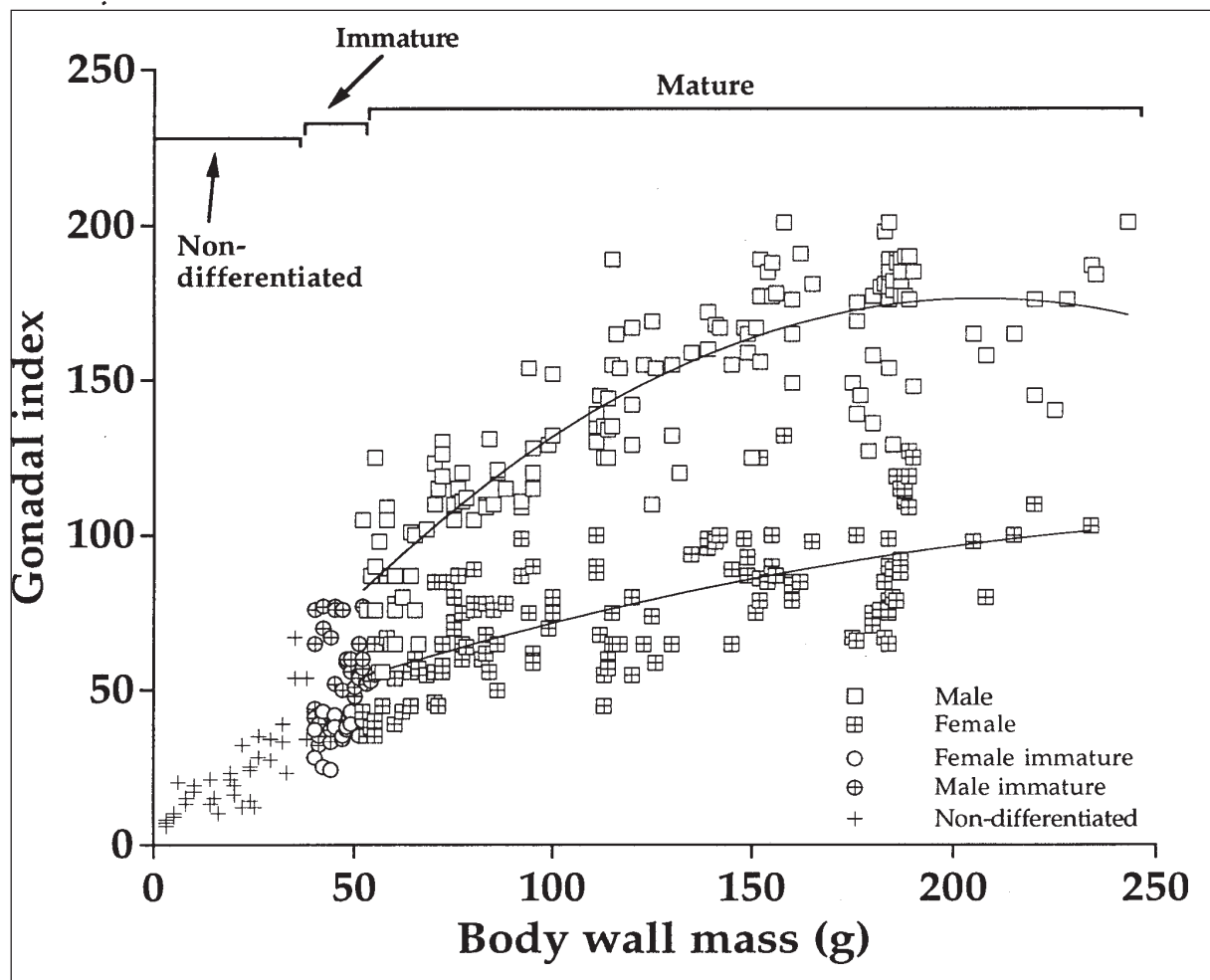


Figure 3: *Cucumaria frondosa*. Relation of the gonadal index to the wet body-wall mass (n=567) in April 1992. The state of maturity of the sea cucumber is indicated for all sampling sizes.

The presence of mature oocytes was monitored in females of increasing body-wall mass. We found that females between 70 to 80 g possessed around 300 mature oocytes (figure 4). After reaching 120 g of body wall mass, the number of mature oocytes increased rapidly to attain the maximum mean density of  $8,100 \pm 2,300$  oocytes for individuals with 180 to 250 g of body-wall mass (see Figure 4).

#### Male reproductive cycle

After the early summer spawning, the small tubules mainly contained residual gametes and nutritive phagocytes, characteristic of the recovery stage, until December 1992 and January 1993 (figure 2). During that same period, no significant gametogenetic development was recorded in the large tubules (Kruskal-Wallis,  $p > 0.05$ ). Spermatogenesis was first initiated in the small tubules in early January 1993.

This process was characterised by the appearance of a thin opaque structure, composed mainly of densely-conglomerated spermatogonia, along the inner surface of the germinal epithelium. Following that, the proportion of individuals with small tubules in the recovery stage decreased to less than 10 per cent between December 1992 and February

1993 (see figure 2). The importance of the growth stage increased abruptly during that same interval, and then more subtly until May 1993, when it was observed in the small tubules of 85 per cent of the individuals, prior to spawning.

#### Female reproductive cycle

The female cycle closely resembled that of the males. In May and June of 1992 and 1993, advanced stages (advanced growth and maturity) were found in  $\geq 80\%$  of the large tubules, whereas the earlier stages predominated in the small tubules (see figure 2). In the large gonadal tubules, the post-spawning and recovery stages were almost always absent, and the major evidence of both 1992 and 1993 spawnings was the decrease in mature stages.

In contrast, the mature stages in the small tubules remained rare and the major evidence of spawning was a sharp increase of the post-spawning stage. Oogenesis was initiated in early January 1993, after the characteristic resting period that prevailed just after spawning and through the beginning of January. Subsequent oocyte development was characterised by the growth of the nucleus and cytoplasm and the increase in the ratio of cytoplasm to nucleus volume. With continued growth, oocytes often be-

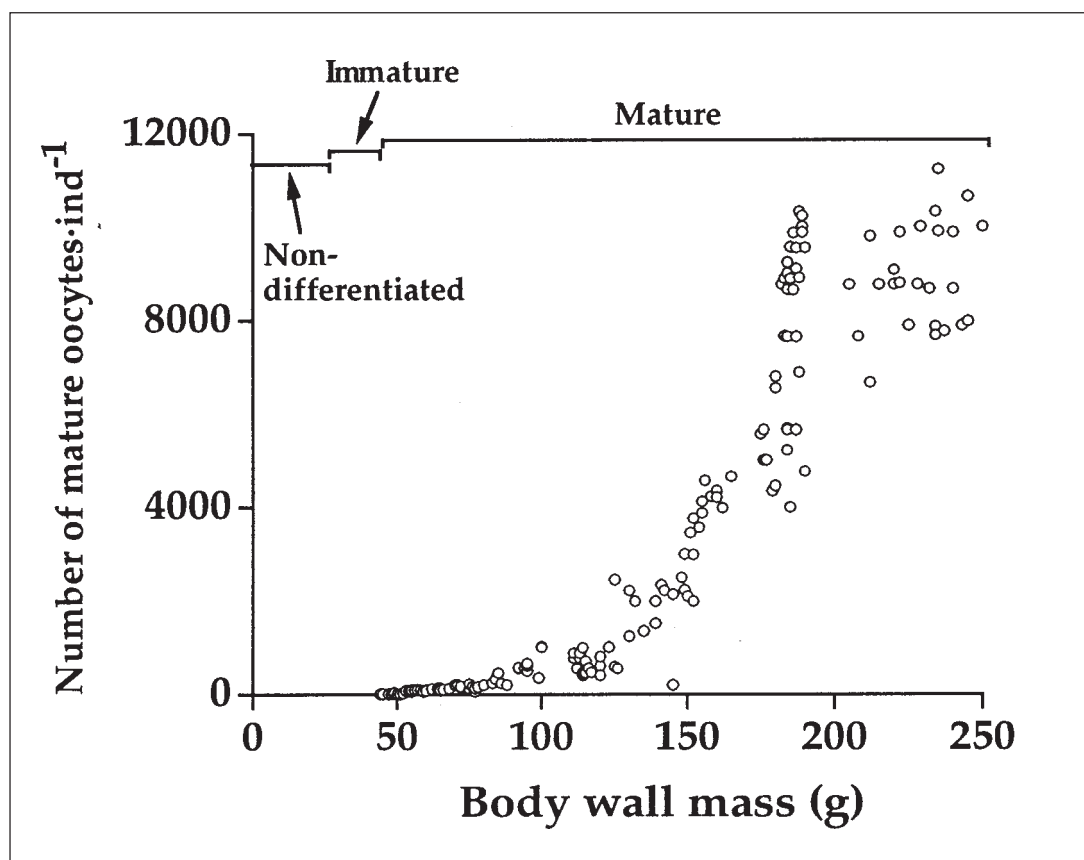


Figure 4: Fecundity and state of maturity of females *Cucumaria frondosa* from less than 1 g to 250 g. These data were collected from individuals dredged in April 1992 before the spawning period.



came irregularly shaped due to spatial constraint within the gonadal tubule.

For males and females, the approach of spawning and the event itself corresponded to an important transition in the gonadal tubule morphology. The small tubules became larger (up to 2.2 mm in diameter), due to the increasing presence of maturing gametes, and progressively entered the lower levels of maturity.

Simultaneously, the large tubules attained full maturity (>3.5 mm in diameter) and were emptied of mature gametes during spawning, causing a decrease in their diameter down to less than 2.2 mm. After spawning, the large tubules had consequently transformed into small ones, with two years of growth ahead, while newly produced large tubules were at the beginning of their last year of growth.

#### *Changes in the body component parameters in relation to environmental conditions*

The major event that occurred in 1992 and 1993 was the drastic drop of the gonadal index in May to June of both years, for both sexes (see figure 5). It coincided with a net decrease in the mean tubule diam-

eter and with a significant decrease in the calorific value of the gonad. This value dropped by 45 per cent in females and by 41 per cent in males (Kruskal-Wallis,  $p < 0.01$ ) (see figures 5 & 6), strongly suggesting a spawning event.

Following this drop was a period of low gonadal index until December 1992, coinciding with the simultaneous and progressive decrease in the energetic content and index of the intestine (content included). The gonadal tubule diameter, the gonadal index and the energy stored in the gonad also remained at their minimum of the year in the June to December interval (see figures 5 & 6).

However, from early January 1993, we observed a slight increase in the gonadal index coinciding with the first sign of tubule diameter increment and growing energy content in the gonad. In March, the energy content increased from  $21 \text{ kJ.g}^{-1}$  to  $27 \text{ kJ.g}^{-1}$  in the female gonads and  $16 \text{ kJ.g}^{-1}$  to  $20 \text{ kJ.g}^{-1}$  in the male gonads. The gonadal index significantly increased from March 1993 to attain a peak in May 1993 (Kruskal-Wallis,  $p < 0.01$ ). An increment was also observed in the tubule diameter and in the calorific value of the gonad, both of which attained their maximum levels for the year (figures 5 & 6).

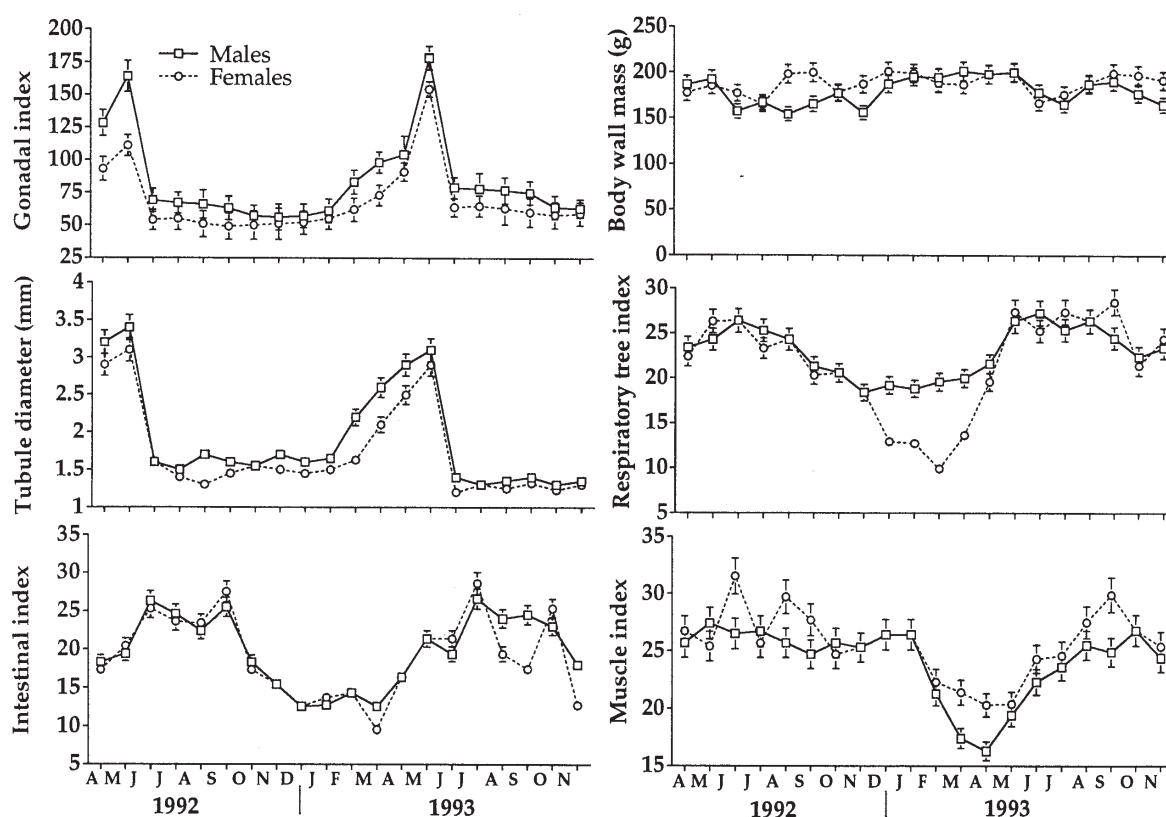


Figure 5: *Cucumaria frondosa*. Seasonal variation of the different body component indices, the mean body-wall mass and the tubule diameter, for males and females, from April 1992 to November 1993. The vertical lines represent the confidence interval (95%).



After the spawning of June 1992 and until February 1993, the index of the respiratory tree decreased progressively and attained its minimum value (figure 5).

The progressive decrease of the index and calorific value of the muscle bands coincided with the initiation of gametogenesis (January – February 1993). It attained a minimum value in April – May, just before spawning in 1993. In the case of male body wall and respiratory tree, indices and calorific value did not show any significant variation over the two years of experiment (Kruskal-Wallis,  $p < 0.01$ ).

Although the female body-wall mass remained constant, its energy content dropped significantly (Kruskal-Wallis,  $p < 0.01$ ) when the food supply decreased in January 1993.

The energy content increased rapidly again the next spring, in correlation with rising food supply in the field (see figure 6). The respiratory-tree index also marked a significant decrease in females (Kruskal-Wallis,  $p < 0.01$ ) (see figure 5).

Total energy content prior to the 1992 spawning was  $\approx 114 \text{ kJ.g}^{-1}$  for females and  $98 \text{ kJ.g}^{-1}$  for males. In both sexes, the gonad accounted for  $\approx 35$  per cent of this value, the intestine (including its content) for  $\approx 17$  per cent, the body wall for  $\approx 19$  per cent, the respiratory tree for  $\approx 12$  per cent and the muscle bands for  $\approx 16$  per cent.

Just after spawning, the total amount of energy in the animals dropped to  $\approx 86 \text{ kJ.g}^{-1}$  in both sexes. This decrease was correlated to a clearly less important contribution from the gonad, representing only  $\approx 19$  per cent of the total amount of energy in a single individual.

#### Relation of gametogenesis with environmental factors

##### Temperature

Spring conditions prevailed at the beginning of the experiment, with a water temperature fluctuating between 3 and 5°C and rising rapidly to attain 3 to 9°C in early spring, until the end of August 1992. The final maturation of oocytes in large tubules and the appearance of the growth stage in small tubules coincided with the rapid increase of water temperature in early spring.

The spawning event, occurring between mid-May and mid-June of both years, coincided with the peak of this warming period. Beginning in early September 1992, the water temperature dropped abruptly to reach its minimum annual value in

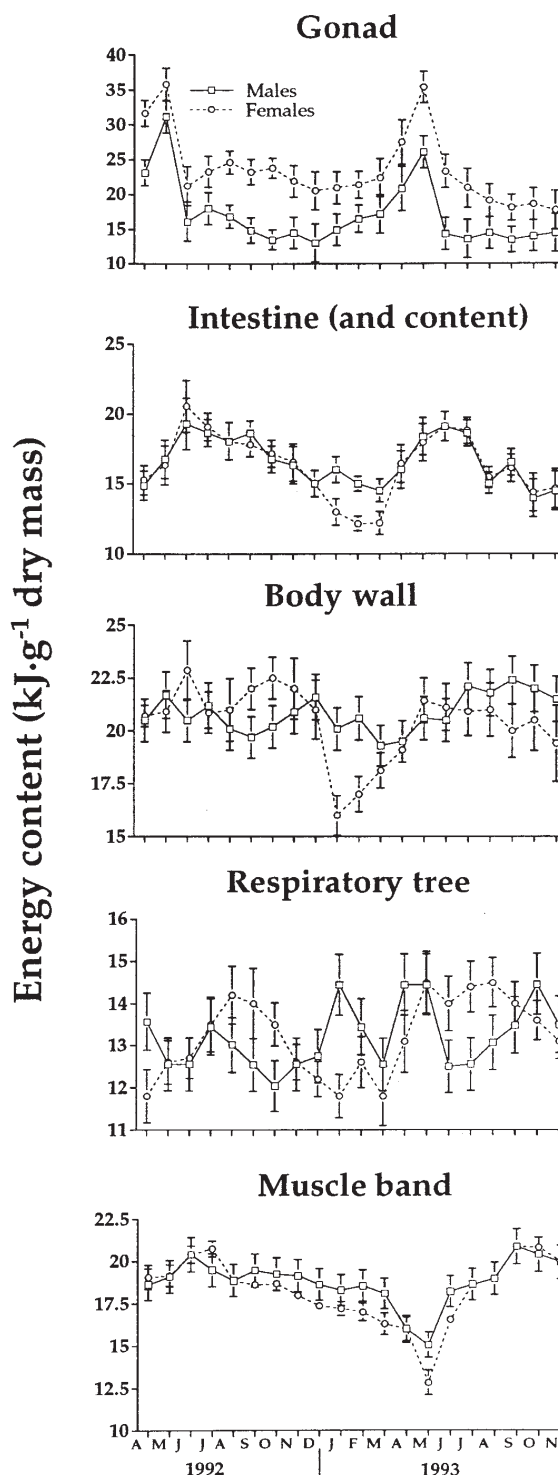


Figure 6: *Cucumaria frondosa*. Seasonal variation of the energy content in 1 g dry mass of gonad, intestine, body wall, respiratory tree and muscle band from April 1992 to November 1993. The vertical lines represent the confidence interval (95%).

October, with fluctuations between -1 and 1.5°C. This minimum threshold remained until early March 1993, when the warming cycle began again.

## Freshwater run-off and chlorophyll a

Chlorophyll a concentrations at the beginning of the experiment (May 1992) fluctuated around 0.5 and 1 mg.m<sup>-3</sup>. A strong increase in chlorophyll a occurred in mid-June 1992 with a peak at 6 mg.m<sup>-3</sup>, indicating an important phytoplanktonic biomass. Spawning occurred at that time. This high production persisted until August, although the pigment concentrations were not constant and fluctuated sometimes from the highest values (≈7 mg.m<sup>-3</sup>) to less than 1 to 2.2 mg.m<sup>-3</sup>.

During late fall and winter, the chlorophyll a concentrations were minimal and fluctuated around 0.2mg.m<sup>-3</sup>, until next spring. The same cycle roughly repeated itself in 1993. The fresh-water run-off reached a maximum in March and April (1992 and 1993), attaining 3,000 to 8,000 m<sup>3</sup>.s<sup>-1</sup>. The abrupt decrease of freshwater run-off coincided with the increased concentration of chlorophyll a in the water column, in June of both years. The minimum value of about 500 to 700 m<sup>3</sup>.s<sup>-1</sup> was maintained until the next spring.

## Photoperiod

The minimum day-length was observed during the third week of December 1992 (8.2 h.d<sup>-1</sup>). From this time, the day-length increased progressively and attained its maximum during the third week of June (15.5 h.d<sup>-1</sup>). After reaching this maximum, the day-length began to decrease progressively to return to its minimum value, in December 1993.

## DISCUSSION

### *Gonad morphology versus geographical location*

The gonad morphology and reproductive cycle of *Cucumaria frondosa* was not uniform over the scope of sampling sites, along the north-east American coast. The gonad of *C. frondosa* was divided into two distinct classes of gonadal tubules in northern latitudes, while uniformity among the tubules was evident south of mid-New Brunswick. Very different local environmental conditions may regulate this morphological disparity.

Satellite images and in situ data indicate a mean annual difference of 8°C, between the northern and the southern surface of the Gulf of St Lawrence (J. Chassé & D. De Lisle, personal communications). This temperature transition, occurring along the coast of New Brunswick, is probably a consequence of depth variations. Specific gonad morphology was also correlated with the length of the vegetative season in those areas.

Favourable conditions for primary production spread from April to October in the southern regions (Roman & Tenore, 1978; Fournier et al., 1979; Bowman et al., 1981), whereas they occur only from June to September–October around the St Lawrence Estuary (Levasseur et al., 1984; Theriault & Levasseur, 1985, 1986).

As a result, sea cucumbers south of New Brunswick benefit from a longer feeding period. This, combined to a higher mean annual temperature, may favour the development of their entire gonad over a single year, and increase the number of gametes that reach maturity in that interval.

From their work on *Stichopus californicus*, Smiley & Cloney (1985) and Smiley (1988) inferred that the presence of different classes of gonadal tubules, and their successive maturation, was as a constant trade among many species of sea cucumbers.

However, Sewell (1992) demonstrated that the reproductive cycle and gonad morphology varied within samples of *S. mollis*, collected at different latitudes. Like our data on *Cucumaria frondosa*, those results tend to promote the occurrence of a certain plasticity in the gonad morphology of sea cucumbers, when members of the same species are submitted to different environmental conditions.

### *Cucumaria frondosa from the St. Lawrence Estuary*

#### *Size at sexual maturity and fecundity*

It is well known that a certain minimal body size is necessary before an individual becomes reproductive (Lawrence, 1987). Young *Cucumaria frondosa* reached sexual maturity at about 55g (wet body-wall mass), a very small size compared to the maximum 350 g encountered in the field. This may suggest that, from that moment on, gonadic and somatic growths have to share the available energy, with the probable consequence of reducing the rate of somatic development soon in the life of the sea cucumber.

However, Hamel & Mercier (in press) observed that the growth rate of *C. frondosa* increased significantly well before and after reaching the sexual maturity, in laboratory and in the field. The growth rate did not seem affected by the level of development of the gonad. This may be related in part to the fact that food availability, in terms of planktonic material, is not limiting in the St. Lawrence Estuary, exceeding by far the need of the young sea cucumber and allowing the concurrent growth of somatic and reproductive tissues.

This small size at sexual maturity was also observed in the sea cucumber *Psolus fabricii* (Hamel et al., 1993) and in the sea urchin *Strongylocentrotus droebachiensis* (Munk, 1992).

The fecundity of females *Cucumaria frondosa* increased rapidly with size. It attained about 9,000 mature oocytes·year<sup>-1</sup> in individuals of 170 g. The annual fecundity of *C. frondosa* is higher than that of other dendrochirotrida, such as *C. pseudocurata* (340 oocytes) and *Psolidium bullatum* (3,000 oocytes), but roughly similar to the fecundity of *C. fallax* (8,800 oocytes) and much lower than that of *C. piperata* ( $1.1 \times 10^4$  oocytes), *Psolus chitonoides* ( $3.5 \times 10^4$  oocytes), *Pentamera populifera* ( $3.5 \times 10^4$  oocytes) and *C. miniata* ( $1.32 \times 10^5$  oocytes) (see review McEuen 1987). In regards to the size of the organism, the number of gametes synthesised by *C. frondosa* seems quite low, compared for instance with *P. chitonoides*, a smaller species that produces larger amounts of gametes.

However, the great abundance of *C. frondosa* in the study site (5–15 ind.m<sup>-2</sup>), their spawning behavior (Hamel & Mercier, 1995), and the large size of their oocytes may ensure a high fertilisation success despite the low fecundity of the species. The same conclusion was formulated by Levitan (1993) for the sea urchin *Strongylocentrotus*, which also synthesises small amounts of large oocytes.

#### *Gametogenesis and reproductive cycle*

The annual reproductive cycle of *Cucumaria frondosa* from the St Lawrence Estuary culminated in an early summer spawning. Gametes were released from large gonadal tubules that had matured over the previous year, while small gonadal tubules contained only gametes that would need another year of growth to become mature. Two years of growth seem necessary for each tubule to reach maturity.

Our data of gonad morphology, gametogenesis initiation and development, as well as spawning period, are similar to those obtained with *Psolus fabricii* (Hamel et al., 1993), another sea cucumber found in the Lower St Lawrence Estuary.

However, our results differ from those obtained by Smiley & Cloney (1985) and Smiley (1988) with *Stichopus californicus*. The location of the different classes of gonadal tubules was correlated with their degree of maturity in *S. californicus*, but was totally random in *Cucumaria frondosa*.

Also, the tubules that were implicated in the spawning of *S. californicus* resorbed afterward, whereas

they did not in *C. frondosa*. In fact, precursor cells became visible along the germinal epithelium of those gonadal tubules the next January, while growth continued for a subsequent year.

Gametogenesis in *Cucumaria frondosa* was initiated in early January, after a long period of recovery. Intense gamete synthesis and reserve storage began in March and continued until the spawning event, in mid-June. Such results are quite different from those obtained for the same species by Jordan (1972) on the east coast of Maine and by Coady (1973) in Newfoundland.

Coady (1973) indicated that the spermatogenesis in *C. frondosa* was initiated in early June, following the spawning period, and continued until late November. He observed that females did not mature in synchrony with males.

Moreover, Coady (1973) mentioned that the majority of males reached maturity several months before spawning, while the final maturation of oocytes occurred just before their release. As for Jordan (1972), he stated that oogenesis was initiated in early summer and maturity was attained in early winter, while spermatozoa were constantly produced.

Those two studies came up with different results which are also opposed to our own. The sea cucumbers collected close to the study sites of Jordan (1972) and Coady (1973), on the southern coast of Newfoundland (station 3) and along the coast of New England (stations 12, 13, 14), present a single class of gonadal tubules. This may explain in part the difference observed between the gametogenetic cycles of *C. frondosa* from the St Lawrence Estuary and those living southerly.

The similarity between male and female gametic development strongly suggests the importance of environmental factors in its regulation. The only environmental factor that can be correlated to the initiation of gametogenesis in early January appears to be photoperiod. The first appearance of oogonia and spermatogonia nests along the germinal epithelium of the small gonadal tubules coincided with the winter solstice, which marks the increase of daylength. At that time, salinity and water temperature in the study site were roughly constant, around 29 and 0°C, respectively, while chlorophyll a concentration was virtually nil and the intestine was mainly filled with non-living material, indicating that food was scarce.

Those factors could not have had much influence on the initiation of gametogenesis. Photoperiodic regulation of gametogenesis was proposed for vari-

ous species of echinoderms such as the sea urchin *Strongylocentrotus purpuratus*, the sea stars *Pisaster ochraceus* (Pearse & Ernisse, 1982) and *Asterias vulgaris* (Pearse & Walker, 1986) as well as other species of sea stars from the west coast of the United States (Pearse et al., 1986a, b). Photoperiodic control was also suggested for the sea cucumber *Psolus fabricii* (Hamel et al. 1993). Later on, in early spring, the analysis of intestinal content and chlorophyll a concentration in the field showed that food availability was increasing, along with rising temperature. This period coincided with a net increase of gamete synthesis in *Cucumaria frondosa*.

According to Lawrence (1987), rarely are the testes larger than the ovaries. However, the gonadal index of male *Cucumaria frondosa* was higher than that of female by as much as 20 per cent, before the spawning event. This was correlated with the proportionally larger and heavier gonad of male, also observed in the sea cucumber *Psolus fabricii* (Hamel et al., 1993).

Inversely, Tuwo & Conand (1992) indicated that female *Holothuria forskali* had higher gonadal indices than male. Other sea cucumbers, like *Aslia lefevrei* (Costelloe, 1985), *Parastichopus californicus* (Cameron & Fankboner, 1986) and *Stichopus mollis* (Sewell & Bergquist, 1990) present no disparity between male and female gonadal indices.

The calorific value of 1 g dry mass of gonad was about 10 to 18% higher in female than in male *Cucumaria frondosa*, prior to the spawning period. Thus, male gonads were probably bigger, mainly because less energy is required to synthesise an equivalent amount of gametes. Especially since no difference can be observed in the maximum body size attained by males and females. Lawrence & Lane (1982) indicated that ovaries are richer than testis even if they are of the same size and more sperm may be produced per unit of gonad volume. It therefore appears that the reproductive effort of *C. frondosa*, in terms of the energy invested in gamete synthesis, is equivalent in males and females.

During the period of low food availability, the energy content in the female body wall seemed to decrease, even though its mass did not vary significantly. This suggests that a metabolic activity requiring energy was in progress, as also proposed by Ong Che (1990) for the sea cucumber *Holothuria leucospilota*. A translocation of energy to the gonad, during the early phase of gametogenesis, possibly occurred at that time. Female gamete synthesis probably required more energy, at first, than that of male, in which the translocation process is less clearly defined.

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## Gamete dispersion and fertilisation success of the sea cucumber *Cucumaria frondosa*

by Jean-François Hamel<sup>1</sup> & Annie Mercier<sup>1</sup>

### Abstract

During spawning in the field, the buoyant oocytes of *Cucumaria frondosa* progressed to the surface, and fertilisation occurred as they made their way through a dense layer of spermatozoa, spread over the spawning site. Consequently, the proportion of fertilised eggs increased with distance from the bottom, passing from 27% near the spawning population to about 85% at the surface. Asynchronous gamete release from both sexes combined with oocyte buoyancy and prolonged sperm potency therefore appear as determinant factors leading to fertilisation success in this species.

### INTRODUCTION

In recent years, a number of studies used field observations, laboratory experiments, or both, to determine the fertilisation success of echinoderms under various current conditions and population densities (Pennington, 1985; Sewell & Levitan 1992; Levitan et al., 1992; Young et al. 1992; Levitan, 1993; Benzie & Dixon, 1994; Babcock et al., 1994; Benzie et al., 1994; Hamel & Mercier, 1995a).

Some even predicted the fertilisation success according to different physical parameters (Denny & Shibata, 1989; Levitan et al., 1991; Denny et al., 1992; Young et al., 1992) or to the in situ gamete abundance and fertilisation rate (Benzie & Dixon, 1994; Babcock et al., 1994; Benzie et al., 1994).

Pennington (1985) even conducted a field experiment in order to estimate the natural fertilisation rate in *Strongylocentrotus droebachiensis*. Most of those studies used KCl to induce spawning in laboratory or directly in the field. Not using this artificial technique, Sewell & Levitan (1992) described the in situ fertilisation success during a natural spawning of the sea cucumber *Cucumaria miniata*.

Other exceptions comprise the field measurement of sperm dispersal and fertilisation in the colonial hydroid *Hydractinia echinata* (Yund, 1990) and the work of Benzie & Dixon (1994), Babcock et al. (1994), Benzie et al. (1994) on the crown-of-thorn *Acanthaster planci*.

However, no continuous observation of the fertilisation success was ever made during a natural spawning, considering the number and position of individuals on the substrate and the influence of environmental parameters.

Our study was not designed to build a predictive model of fertilisation success in *Cucumaria frondosa*, but rather focused on evaluating the sequence of events that takes place upon the release of gametes in the water column. To achieve that, we kept a continuous record of sperm and oocyte concentrations and fertilisation rates in the field over several hours, during a natural spawning event.

We also concurrently monitored various environmental factors. This experiment brings new light to the understanding of gamete behavior in *C. frondosa* and perhaps other broadcast spawners.

### MATERIALS AND METHODS

#### Monitoring of the spawning event

The experiment was conducted at Les Escoumins, Lower St Lawrence Estuary, eastern Canada, in summer 1992. Using SCUBA, we monitored gamete release, dispersion and fertilisation during a natural spawning of males and females *Cucumaria frondosa*. Beginning with the first signs of spawning, divers took turns underwater by groups of up to 10 divers for 50 hrs, until the end of spawning. The divers were positioned at different depths using an electronic depth meter. Each team dived for a maximum of 35 mins at intervals of 3–4 hrs or longer. Most of the measures were taken above 10 m (only a few divers needed to descend at 15 m). The monitoring of environmental parameters and the spawning sequence are described in a previous paper (Hamel & Mercier, 1995b).

#### Gamete behaviour (single individual)

These data were collected during the first isolated spawning events, without artificial stimulation. We studied only spawning individuals at least 20 m

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away from the closest spawning neighbour. The distinct peristaltic movement of the body, from the anus to the mouth, and the well-extended gonopore were the major signs visible for divers. After locating a single spawning individual, the divers (without disturbing the animal) placed a transect line (25m long) parallel to the direction of current, maintained by a buoy at the surface, and attached to the nearest boulders.

This operation was performed in less than 15 mins. All individuals that initiated gamete release before the final installation of the transect line were rejected. Water samples were collected with Niskin bottles (2.8 l) at various depths over a spawning individual, from the beginning of spawning (time 0), and at regular interval until 150 mins. The number of spermatozoa was determined in 5 subsamples of 2 ml under a microscope with an hemacytometer.

The abundance of oocytes was assessed in 2 subsamples of 1 l, using a binocular. The laboratory work involving microscopy was carried out within an hour in nearby installations. We also noted the progression of oocytes in the field along a 3 m long graduated tube, using 5 replicates, during both slack and flood tides.

#### ***Gamete behaviour (massive spawning)***

Additional underwater data were taken during the massive spawning (when more than 65% of the observed individuals were spawning), to evaluate the gross male and female gamete concentrations at various depths until the end of this event. Again using Niskin bottles, 5 samples of water were taken at regular intervals (between 30 and 50 mins) for more than 6 hrs. Gamete abundance was evaluated as previously described. The first male spawning observed in the study site marked time 0 of collection.

#### ***Fertilisation success during spawning***

We recorded the percentage of fertilised oocytes present at different depths and at the surface of the water, at regular intervals (about 50 mins), during the entire female spawning. Using Niskin bottles (2.8 l), a sample of water (generally containing oocytes and spermatozoa) was collected at each depth (0, 5, 10, 15 m) and was injected within 5 mins with 25 ml of 37% formaldehyde to stop further development or fertilisation of the eggs.

Fertilisation was verified by staining the sample of gametes with the DNA-specific dye Hoechst 33258 and observing it under fluorescence microscopy (Leitz Diaplan fluorescence microscope) to deter-

mine the presence of male pronuclei in the eggs. The fertilization success was also estimated under a light microscope from evidence of fertilization membrane elevation, presence of polar body or cellular division.

## **RESULTS**

### ***Spawning of a single individual***

Because of the low variability in gamete densities between individuals ( $\leq 15\%$ ), the data from all single individuals of the same sex were combined (7 males and 9 females). The results are expressed as an average for all individuals observed over the 150-min period.

#### ***Male***

Within the first 5 min of gamete release, a rapid increase of the spermatozoa concentration within 3 m of the spawning individual occurred (figure 1). This concentration fluctuated around  $1 \times 10^5$  spermatozoa.ml<sup>-1</sup> at time 0 near the spawning individual, and increased rapidly to reach a maximum of  $10 \times 10^5$  spermatozoa.ml<sup>-1</sup> after 10 mins, within 0.5 m of the spawning individual. At first detected only within 0.5 m of the spawning male, the spermatozoa slowly dispersed and could be seen at 3 m after 30 s, at 3.5 m after 5 mins, and at 4.5 m after 10 mins.

At that time, white clouds of sperm were dispersing laterally and vertically in the water column more than 3 m away from the spawning individual. After 15–30 mins, the maximum density of spermatozoa was observed, combining the observations at all depths studied. The spermatozoa concentration reached about  $1.8 \times 10^5$  spermatozoa.ml<sup>-1</sup> at 7 m of distance and remained very high near the spawning individual where it never exceeded about  $10 \times 10^5$  spermatozoa.ml<sup>-1</sup> (see figure 1). After 100 mins, the spermatozoa densities decreased rapidly near the spawning individuals ( $< 0.1 \times 10^5$  spermatozoa.ml<sup>-1</sup>), which at that time had ceased to release their gametes. However, the concentration remained high away from the individuals, attaining the highest concentration after 150 mins at 7 m, with  $4.5 \times 10^5$  spermatozoa.ml<sup>-1</sup> (see figure 1). The spermatozoa densities remained considerable in the plume of gametes throughout the spawning, especially near the water surface.

#### ***Female***

At the time female spawning was initiated, spermatozoa densities were around  $1.5 \times 10^6$ .ml<sup>-1</sup> due to massive male spawning. As soon as a female began

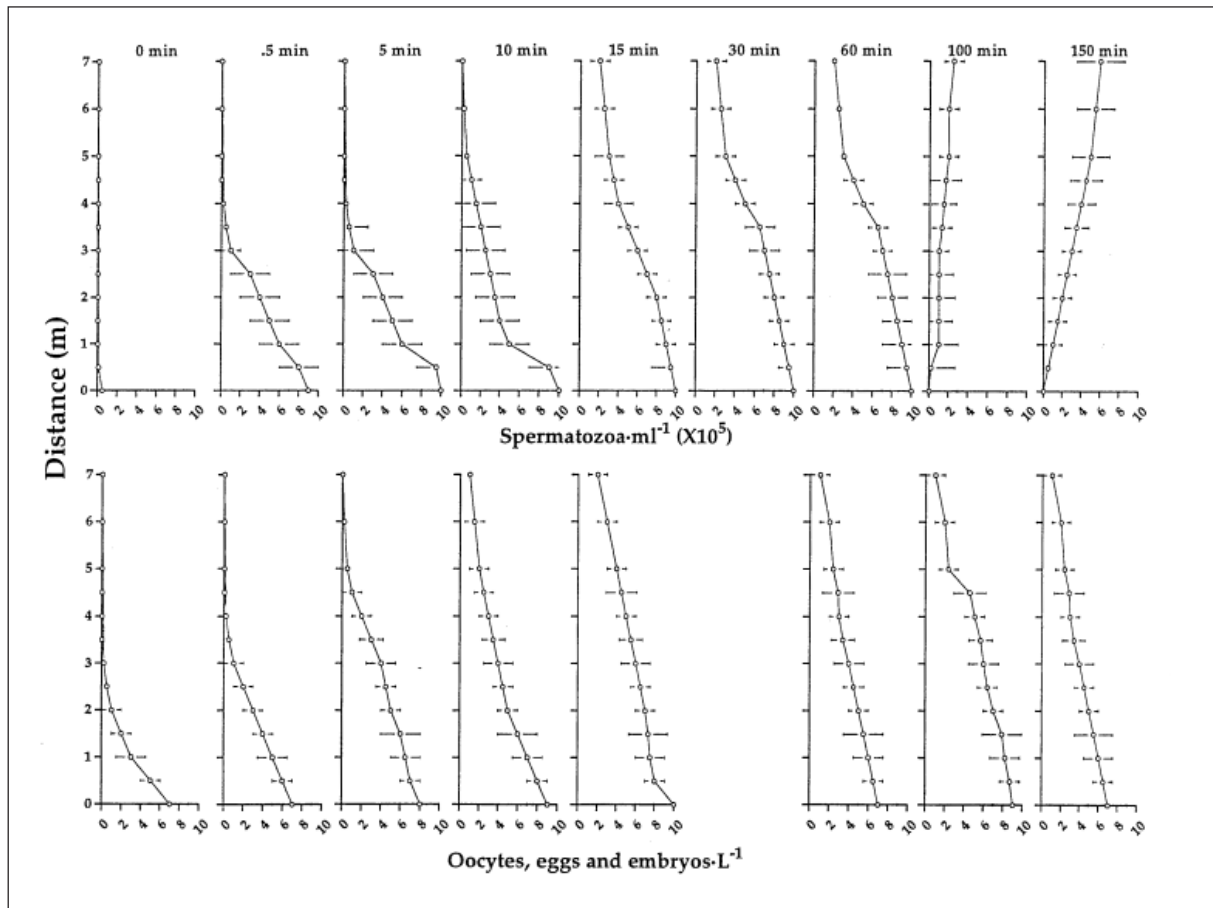
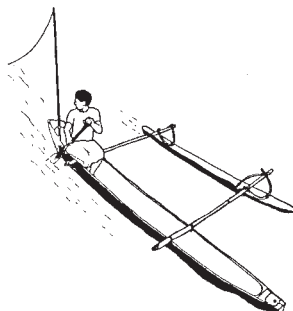


Figure 1: *Cucumaria frondosa*. Density of male or female gametes, released by a single sea cucumber, from the beginning (time 0 min) to the end of spawning (time 150 mins). The horizontal lines represent the 95% confidence interval.

to release gametes, the density of oocytes around it increased rapidly, attaining 7 oocytes. $\text{l}^{-1}$  in less than 30 s near the individual, and 2 oocytes. $\text{l}^{-1}$  within 3 m.

After 10 mins, the oocyte density attained 9 oocytes. $\text{l}^{-1}$  within 0.5 m and gametes were detectable up to 7 m away from the spawning individual with about 2 oocytes. $\text{l}^{-1}$ . After 15 mins, the maximum density of oocytes was observed in the water column, both near and away from the spawning individual, attaining about 10 oocytes. $\text{l}^{-1}$  and 3 oocytes. $\text{L}^{-1}$ , respectively (see figure 1). Following that, no significant change in oocyte density was observed, whatever the depth, until the end of the experiment.



The very buoyant oocytes of *Cucumaria frondosa* reached the water surface and spread in a dense layer (2–3 m thick) below the sea surface, where thousands of eggs developed. The majority of oocytes ( $\approx 87\%$ ) progressed at  $0.75 \pm 0.2 \text{ m} \cdot \text{min}^{-1}$  during slack tide, but this rate was increased drastically when measurements were made during the flood tide. Then, the oocytes or eggs moved up at an average of  $2.2 \pm 0.5 \text{ m} \cdot \text{min}^{-1}$ , while the current velocity near the bottom was between 2 and 5  $\text{cm} \cdot \text{s}^{-1}$ . Only immature oocytes, with a poorly developed vitelline reserve, sank to the bottom.

### Massive spawning of males and females

Occurring well after the first isolated spawnings in both sexes, the massive spawning was also monitored. Between 65 and 80% of males and females were spawning (Hamel & Mercier, 1995b), and the amount of gametes in the water column was already high as we began to record them (see figures 1 & 2). Sperm densities at the beginning of the observations were uniform between the surface and 15 m, showing an average of  $6.5 \times 10^6$  spermatozoa. $\text{ml}^{-1}$ . Those densities remained uniform until

850 mins, despite the continuous supply of new gametes from spawning individuals. The maximum densities recorded were observed after 850 min, with about  $15.5 \times 10^6$  spermatozoa.ml<sup>-1</sup> near the bottom (15 m). By 950 min, the majority of males ( $\geq 93\%$ ) had stopped spawning and the sperm densities began to decrease rapidly near the bottom, reaching their lowest value ( $\approx 2.5 \times 10^6$  spermatozoa.ml<sup>-1</sup>). When female spawning was at its maximum, involving about 83% of individuals (roughly 60 mins after maximum male spawning (see Hamel & Mercier 1995b), the fertilized oocytes undergoing the first cleavage were very abundant just below the surface (about 40 oocytes.l<sup>-1</sup>).

However, the oocyte densities increased continuously in the water column to reach about 100 oocytes.l<sup>-1</sup> after 800 min near the bottom, and about 40 oocytes.l<sup>-1</sup> near the surface. After more than 850 mins, the concentration of oocytes increased rapidly at the surface and reached 180 oocytes.l<sup>-1</sup> after 950 mins. After 1050 mins, the vast majority of

females stopped spawning and the oocyte densities decreased near the bottom, falling to less than 10 oocytes.l<sup>-1</sup>, while the density remained high (140 oocytes.l<sup>-1</sup>) near the surface (see figure 2). Spawning within the entire population was over after about 24 hrs. A single individual, male or female, spawned during about 2 or 3 hrs. Spawning of the majority of individuals occurred in a small 3-hrs interval, during which more than 65% of the population was releasing gametes.

### Fertilisation success

Immediately after the first release of oocytes in the water column (600 mins), the fertilisation rate remained low close to the gonopore with only 9% of the oocytes fertilized (see figure 3). After 620 mins, about 82% of the oocytes collected near the surface were fertilised compared to 15% near the spawning females. The proportion of fertilization success was never higher than 27% near the spawning female (figure 3).

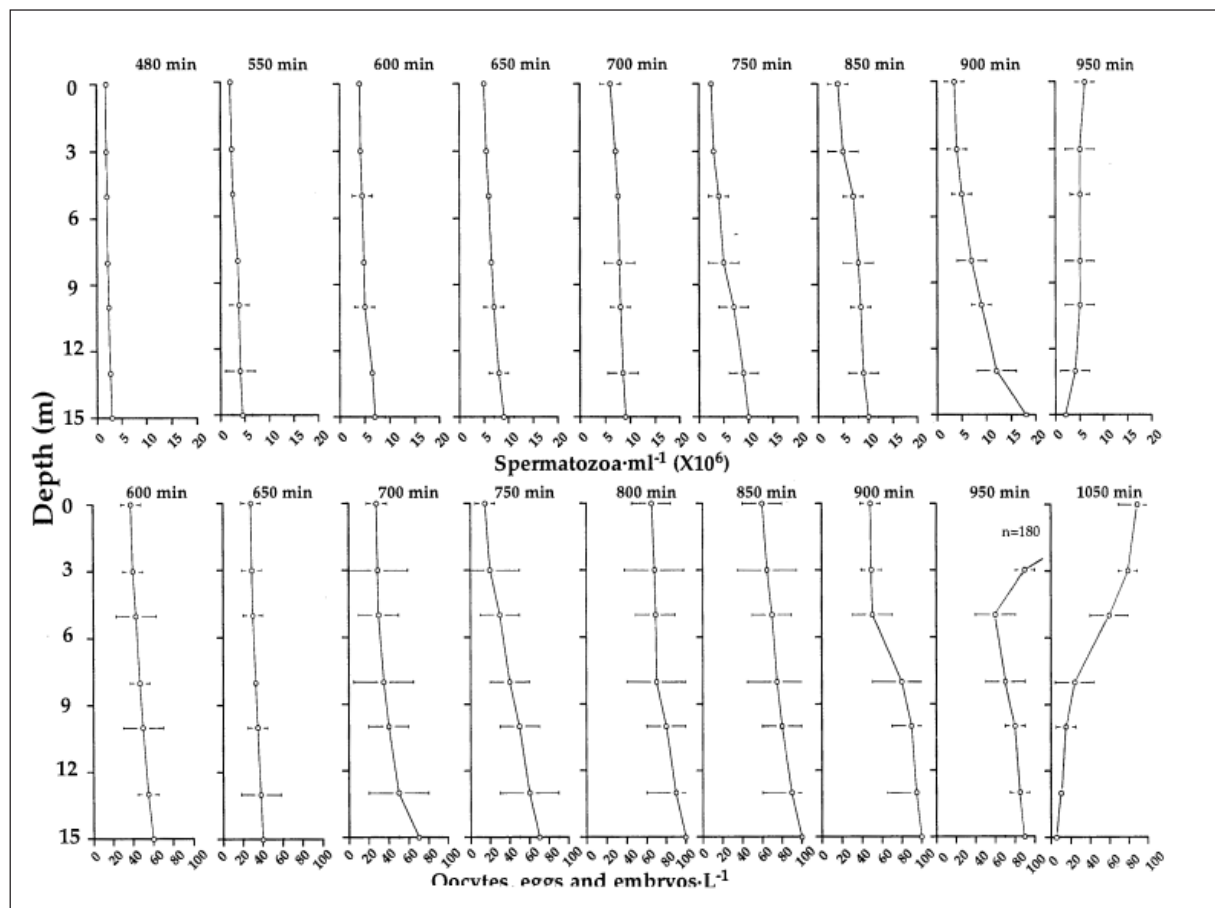
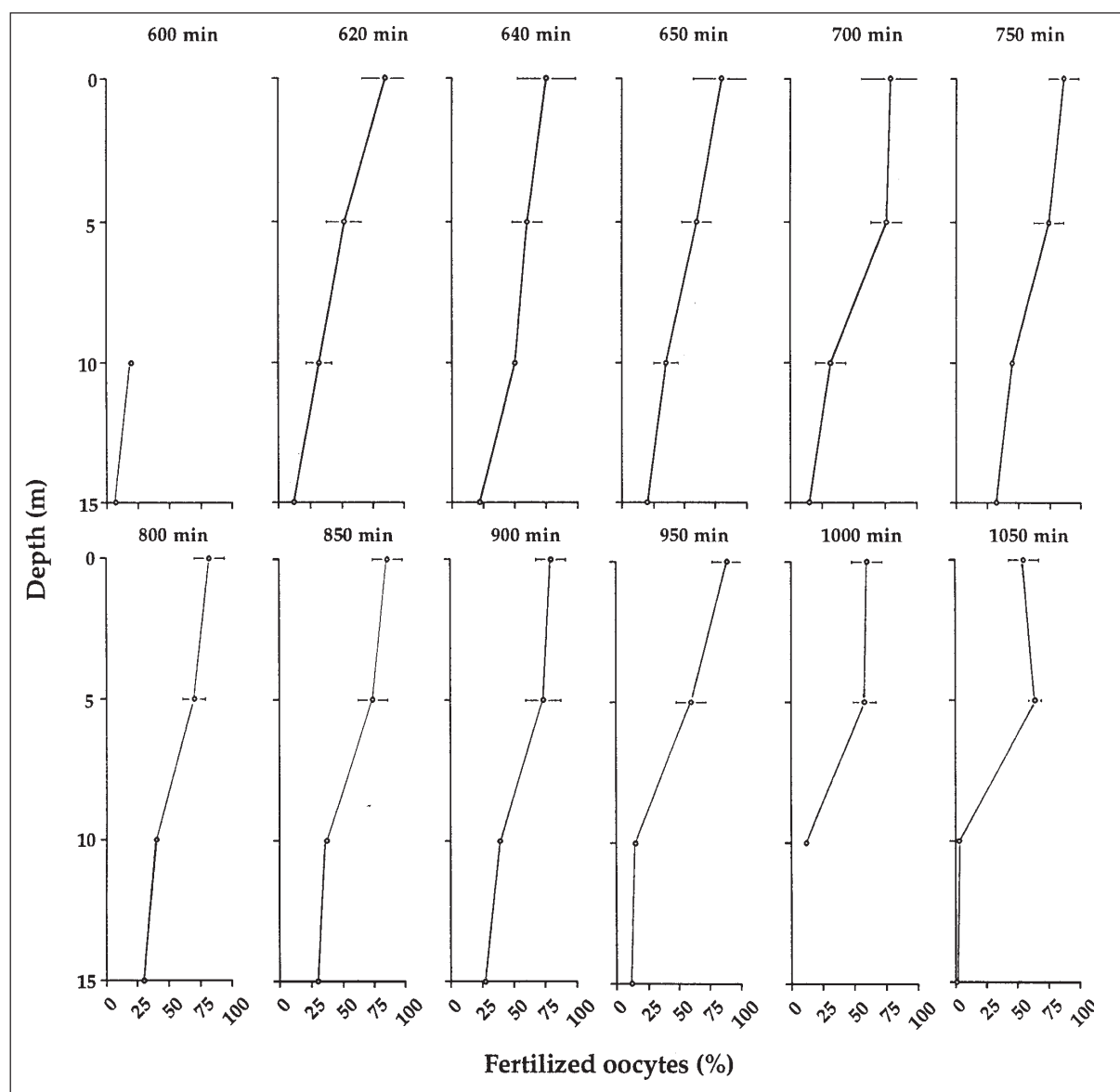


Figure 2: *Cucumaria frondosa*. Integrated value of gamete densities in the water column (from 15 m to the surface) for males and females, throughout their respective massive spawning, in June 1992. The time above the graphics corresponds to the time elapsed since the first record of male spawning. The horizontal lines represent the confidence interval (95%).



**Figure 3: *Cucumaria frondosa*. Percentage of fertilised oocytes at 15, 10, 5 m and at the surface of the water, throughout the entire female spawning. The time above the graphics corresponds to time elapsed since the first record of male spawning. The horizontal bars represent the confidence interval (95%).**

The overall proportion of fertilised eggs in the entire water column increased to attain a maximum after 640 mins. Following that time, the proportion of fertilised oocytes remained stable until 950 mins. At that moment, the majority of males had stopped spawning.

Nonetheless, the fertilisation rate remained high near the water surface, where it never decreased below 75 per cent, until the end of the observations. However, from 1000 to 1050 mins the fertilisation success decreased rapidly near the spawning females, becoming virtually nil, but was still high near the surface where it reached about 45% at the end of the experiment.

## DISCUSSION

The data of gamete dispersion and fertilisation success measured in the field during the spawning of *Cucumaria frondosa* differed somewhat from almost every model prediction. They also differed from empirical data collected in nature during the spawning of other marine invertebrates. The only closely resembling results are those presented by Sewell & Levitan (1992) for a congeneric species, *C. miniata* from the west coast of Canada.

Despite the fact that most models took various factors such as current conditions, substrate morphology, density of individuals, distance between individuals and gamete abundance into account, the differences we observed may result from numer-



ous other factors that are difficult to consider with enough accuracy during modelisation. Spawning synchrony between the sexes, complex aggregative behaviours, chemical communication, gamete viability and behaviour, along with environmental conditions prevailing during natural spawning events, are among the most important variables rarely taken into account. A 1-hr delay between the peak of male and female spawnings of *Cucumaria frondosa* (Hamel & Mercier, 1995b) could appear negligible, but it allowed a maximum concentration of sperm to be attained in the water column ( $3$  to  $18 \times 10^6$  spermatozoa.ml<sup>-1</sup>) prior to female spawning (figure 2).

The asynchronous spawnings also favoured the formation of a cloud of spermatozoa, through which the oocytes passed on their way to the surface, enhancing fertilisation. That is probably why the maximum proportion of fertilised eggs ( $\approx 85\%$ ) was observed in the upper water layer. It was also the case in *C. miniata*, studied by Sewell & Levitan (1992). The maximum fertilisation success we measured in the field corresponded to the maximum success obtained in laboratory with *C. frondosa* by Hamel & Mercier (in press). The 10-hrs sperm potency observed in *Cucumaria frondosa* (Hamel & Mercier, in press) probably played a major role in the concentration of active sperm in the water column prior to female spawning.

This potency is much longer than the 20 mins recorded for the sperm of sea urchin *Strongylocentrotus droebachiensis* by Pennington (1985). He and Denny (1988) indicated that the sperm longevity was probably relatively unimportant in high current conditions, because sperm is rapidly diluted by turbulence. The population of *C. frondosa* observed in the St Lawrence Estuary does live in an area of high energy level, where the tidal amplitude and the current enhanced by the wind are strong.

However, the main spawning event occurred during slack current at low tide (Hamel & Mercier 1995b). The sperm and oocyte concentrations remained high over the spawning population during the experiment, especially during the massive spawning (figure 2). Although some gametes may have been exported outside the bay continually, we suggest that a net residual current and the wind that blew toward the coast favoured the retention of a large proportion of gametes inside the bay and reduced their exportation. This allowed the maintenance of a density as high as  $18 \times 10^6$  spermatozoa.ml<sup>-1</sup> during the massive spawning of the females.

The majority of gametes were spawned during the period of slack current (Hamel & Mercier, 1995b).

The low tide and current conditions, along with the massive spawning of males and females, apparently contributed to minimise gamete dispersion prior to fertilisation, as also suggested by McEuen (1988) for some species of dendrochirotes and by Sewell & Levitan (1992) in *C. miniata*. McDowall (1969) and Sewell & Levitan (1992) proposed that low tide reduces the volume of water into which gametes are diluted and increases fertilisation success.

The density of *Cucumaria frondosa* varied between 5 and 18 ind.m<sup>-2</sup> in the study site, representing a biomass of about 3 to 15 kg.m<sup>-2</sup>, between 10 and 15 m (Hamel & Mercier, in press). This density, combined with an equal distribution of males and females, may also have favoured a high level of fertilisation by maintaining an important concentration of sperm and limiting gamete dilution. The population density was also previously suggested as a major factor influencing the fertilisation success in other species of echinoderms (Levitan, 1991; Levitan et al., 1992; Sewell & Levitan, 1992). Some models of fertilisation success in marine invertebrates tend to integrate many important and realistic factors. The more abundant those parameters, the more closely related to field data are the predictions.

Despite that, numerous difficulties are inherent to in situ measurements of gamete dispersion and fertilisation success, and we believe that more direct and careful observations of the various conditions prevailing during spawning are an essential prerequisite to increase the real applicability of models. Especially since most marine invertebrates demonstrate important strategies to regulate their gamete release in order to achieve a maximum fertilisation success (see reviews of Chia & Walker 1991; Smiley et al., 1991, Pearse & Cameron, 1991). Furthermore, the natural spawnings often last several hours or even days, over which the fine environmental conditions vary continuously.

Numerous factors seem to optimise fertilisation in marine invertebrates, and more precisely in *Cucumaria frondosa*. Population densities, distance between each individual, male to female ratios are certainly important in all species.

In *C. frondosa*, the delay between male and female spawning, the long sperm potency and maintenance of high sperm concentrations in the water column, despite the variable current conditions in the study site, are also essential factors. Finally, the oocyte buoyancy seems to optimize the fertilisation success by increasing the chances of contact with sperm. This assemblage of factors probably explains in part the high annual recruitment and very dense populations of *C. frondosa* along the North shore of the St Lawrence Estuary.

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## Spawning and asexual reproduction of tropical holothurians

In the Beche-de-mer Information Bulletin #7, Chantal Conand asked for spawning information as well as asexual reproduction observation by fission and regeneration. We have received since then several replies, which are shown below.

### 1. Fission and regeneration:

- Species: *Holothuria atra*.
- Site: Fonadu Island harbour area and north of Gamu Island, Laamu atoll, Republic of the Maldives;
- Habitat: both areas are flat reef areas of about 1–2 metres deep;
- Date: June 1995 (near the site of our laboratory, regenerating animals are seen throughout the year);
- State of regeneration of fission: both anterior and posterior parts were seen in various stages of regeneration;
- Number of regenerating and non-regenerating animals: regenerating animals are frequently seen whereas in the area north of Gamu regenerating animals are not frequently seen;
- Variations in behaviour: none observed;
- Observers: N. Reichenbach, Y. Nishar.

### 2. Spawning

#### 2.1 La Réunion

- Site: Indian Ocean, La Réunion, La Saline Reef [back reef, sandy bottom], depth: 0.5 m
- Date: 15/2/95 at 18h00, low tide, full moon;
- Species: *Bohadschia vitiensis*
- Remarks: two individuals were in spawning posture but sexes have not been identified. No other species with typical postures were observed around.
- Observer: P. Durville

#### 2.2 New Caledonia

- Date: 15 February 1996
- Time: 17h00
- Place: Baie des Citrons, Noumea, New Caledonia
- Species: *Bohadschia marmorata*
- Moon phase: New –4

- Sea surface temperature  $\approx 28^{\circ}\text{C}$
- Tide: High tide at 16h30
- Remarks: Observation was made, while swimming with mask and snorkel, at Baie des Citrons, a very popular beach of Noumea. *B. marmorata* is abundant in this sandy bay, it can be seen from 3 metres to 15 metres depth with, in some places, concentrations of more than one individual per square metre. At time of observation, about half of the individuals observed had their body half erected and were spawning. The total time of spawning is not known as the observation lasted only for one hour. However, it should be noted that no spawning was observed during a one hour swim the day before (14 February) and the day after (16 February) at approximately the same time (17h00–18h00).
- Observer: Aymeric Desurmont
- Date: 15 February 1996
- Time: 17h00
- Place: Baie des Citrons, Noumea, New Caledonia
- Species: *Actinopyga echinites*
- Moon phase: New –4
- Sea surface temperature  $\approx 28^{\circ}\text{C}$
- Tide: High tide at 16h30
- Remarks: *A. echinites* is not as abundant as *B. marmorata* at the place of observation. Only 20 individuals could be observed during the one-hour swim and only one was found spawning. This individual had half of its body buried in the sand and the other half erected, moving slowly back and forth. It was interesting to note that this individual was in the middle of a concentration of spawning *B. marmorata* (about 20 individuals in 4 square metres). As for *B. marmorata*, no spawning was observed on the day before and the day after.
- Observer: Aymeric Desurmont

## Sea cucumber culture developments on the west coast of Canada

by Ian Sutherland<sup>1</sup>

The commercial sea cucumber fishery in British Columbia (B.C.) for the giant red or California sea cucumber *Parastichopus californicus* began in the early 1980s. This species is harvested along the west coast of the United States and Canada, typically for its body muscle strips and skin.

While a strong demand for the product has continued, landings from the small fishery in B.C. have decreased in recent years as a result of quotas imposed by the Canadian government to conserve stocks. In 1995, a quota of approximately 233 tonnes (split, eviscerated weight) for the B.C. coast was divided evenly to 84 licences.

As fishery catches decline for many species, people around the world are focusing on actively increasing production through aquaculture or enhancement programmes. In B.C., businesses from both the sea cucumber fishing industry and the shellfish aquaculture sector have been examining such methods for increasing sea-cucumber production. As of December 1995, three groups, each with different but complementary goals, are in the early stages of projects geared for B.C.'s sea cucumber species, conditions and regulations.

B.C.'s licenced sea cucumber fishers in the Pacific Sea Cucumber Harvesters Association joined together with Fan Seafoods Limited and Manatee Holdings Limited, two shellfish aquaculture companies with roots in the fishing industry, to look into options available for sea-cucumber aquaculture and enhancement. Beginning in early 1995, with assistance from the Partners Program of the B.C. Ministry of Agriculture, Fisheries and Food, this group collected information on activities in the field in other parts of the world, created a reference library, started a B.C. Sea Cucumber Newsletter and sent a mission to Japan to see, first hand, the impressive developments in that country.

As a result of this fishery membership and a new Individual Quota system that has given B.C. sea cucumber fishers more control of their destiny, future activities of the group will likely be primarily directed toward enhancement of the common fishery resource. The group hopes that in the near future they will be able to work together with federal and provincial government agencies to set aside selected areas where they can test and develop enhancement

techniques as well as gain the information that is necessary for proper fishery management.

It appears that worldwide, the focus of most programmes is towards the increase of sea-cucumber populations over extensive areas. This is typically done through the use of hatchery-produced seed raised to a suitable size and out-planted to open areas, where it is provided with varying levels of care and ultimately harvested.

Aquaculture operations at this time in B.C., however, normally contain cultured animals in some way in relatively restricted areas leased by aquaculturists from the provincial government. To fit more easily within the existing regulations and operations, activities by two partnerships are using the containment approach to sea-cucumber aquaculture. Both are initially using small sea cucumbers that had settled on oyster culture lines as seed to develop growout techniques. To keep costs low, most hatchery-development work has been delayed until growout methods and technology are better understood.

Sun East Enterprises Ltd, a British Columbia sea cucumber processing and marketing firm, joined Redonda Sea farms Ltd, one of B.C.'s largest shellfish aquaculture companies, in a project to look at basic questions such as whether *P. californicus* could be held, would survive and grow. The one-year study began in later 1994 and was funded jointly by these companies with assistance from the Technology Assistance Program of the Ministry of Employment and Investment.

Subtidal benthic enclosures were examined to provide a similar environment to the typical sector seafloor habitat of these sea cucumbers. Suspended containers were also tested to continue the growth of the sea cucumbers under the same conditions as those from which they were collected and to follow growout methods more typical of B.C. deepwater shellfish culture.

The sea cucumbers were not fed but subsisted and grew, presumably on the material suspended in, or settled from, the water where they were contained. Results were generally positive and have provided direction for future work and a preliminary basis for economic analysis.

<sup>1</sup> IEC Collaborative Marine Research and Development Ltd, 1131 Roy Road, Victoria, British Columbia, Canada V8Z 2X5



The second project using containment is just about to get under way, examining more intensive suspended culture systems as well as the results of feeding to increase growth rates and density of culture. Fan Seafoods Limited, a partner in the fisheries work above, and Gigas Growth Systems Limited, a shellfish aquaculture company focusing on intensive mechanised oyster culture operations, will be undertaking this work with assistance from the Science Council of B.C.

In British Columbia, the viability of sea-cucumber aquaculture and enhancement will depend on the ability to biologically and economically produce sea cucumbers for market and on the regulations

governing activities. Slow early growth for the species and typically low density on fishing grounds are difficulties to be overcome for economic success but increased density and good recovery in culture appear possible. In experimental work to date, however, harvestable size has not yet been reached. As well, regulations are still in the process of being defined by the B.C. Ministry of Agriculture, Fisheries and Food and the Department of Fisheries and Oceans with input from industry members.

The Beche-de-mer information bulletin has been a very useful source of information during these undertakings. The groups mentioned welcome any comments or advice from readers.

## Galapagos News

*Communicated by Chantal Conand  
[Information given by J. Barry, Charles Darwin Foundation]*

The situation in Galapagos was reported up to March 1995 in the *Beche-de-mer Information Bulletin* #7. During the following months, various events have taken place which show that the situation is still very tense.

- *1 September 1995:* the President of Ecuador vetoed a law of 'Special Regimen of Galapagos' which did not address the key management issues which face Galapagos. Galapagos conservation benefitted from this line.
- *3 September 1995:* Threats of violence, followed by a series of disruptive actions, began against the Charles Darwin Research Station and Galapagos National Park property and personnel. These actions have taken place in the port cities on three inhabited islands: Pto. Baquerizo Moreno (San Cristobal Island), Pto. Ayora (Santa Cruz Island), and Pto. Villamil (Isabela Island). Protesters also seized the road on Santa Cruz leading to Baltra Island, closing off the main airport for most people, completely closed the

airport in San Cristobal, and seized Park property in Pto. Villamil. On September 4, 1995, protesters descended on the Station and Park headquarters in Pto. Ayora. Station personnel were evacuated by boat, have then returned, and no one has been harmed. No property has been damaged, but mounds of rubber tires have been incinerated near Park buildings

- *January 1996:* in response to a seizure (January 12) by the Galapagos National Park of illegal sea cucumber catches, and the subsequent arrest and incarceration of 8 Ecuadorian fishermen, approximately 30 fishermen seized the local offices of the Galapagos National Park and threatened to destroy the buildings if their colleagues were not released. The fishermen held the offices for twelve hours before the seizure ended.

This seizure of Galapagos National Park property marks the second such occasion in four months, and recalls the 3 January 1995 takeover related to the same issue of illegal sea-cucumber fishing.

### Miscellaneous

Prices on the retail market in Singapore appeared to be very high in December 1995, up to S\$150/kg for first grade *Holothuria scabra* var. *versicolor* and S\$100 for *Holothuria nobilis* (teatfish) [F. Conand, personal observation].

Sea cucumbers (*Holothuria scabra*, medium grade) were found at Jakarta airport (duty-free shops) at US\$45/kg in January 1996.



B E C H E - D E - M E R

## CORRESPONDENCE

**Correspondence from Beche-de-mer Special Interest Group members***Compiled by Chantal Conand*

From S. Uticke [Australian Institute of Marine Studies, PMB 3, Townsville, Queensland 4180, Tel: 61 7 7534211, Fax: 61 7 7725852, E-mail: S.UTICKE@aims.gov.au]

*Things here seem to develop quite well. I have three populations of S. chloronotus and/or H. atra mixed with some less abundant species on three different islands. I have the chance to sample these and abiotic parameters on a monthly basis via ship-based field trips, so this part is quite OK. In the aquaria system here I keep some H. atra, H. edulis and H. chloronotus, which appears to be more difficult than on Lizard Island.*

*As usual they are shrinking, but this time nearly all of 20 H. chloronotus divided after one to three months (for some coincidental, non-scientific reason, all on weekends!). They appeared to be feeding OK and even spawned at the same time as in the field. Again, as well as some other species which spawned in the field, I only observed males taking part in mass spawnings. Did you ever observe females taking part in mass-spawning events?*



From Dale Sarver [Black Pearls, P.O. Box 525, Holualoa, Hawaii 96725, Tel: 808 3257108, Fax: 808 3253425, E-mail: dalej@aloha.net]

*We are continuing to work on the nursery stages of the Hawaiian sea cucumbers. It is a very tricky problem, but I think we are getting closer. We just got several-*

*hundred Stichopus horrens through the critical period and they are now growing well. We hope we can start making the results more consistent.*



*Stichopus horrens*  
[Photo: Dale Sarver]

From Johan Bell [ICLARM Coastal Aquaculture Centre, P.O. Box 438, Honiara, Solomon Islands, Tel: 677 29255, Fax: 677 29130, E-mail: ICLARM@FFA.gov.sb

*The Australian Centre for International Agricultural Research (ACIAR) has provided ICLARM with restricted core funding for five years to develop methods for the mass-rearing of tropical sea cucumbers for the purpose of enhancing wild stocks.*

*The main aims of the project are to develop reliable methods for inducing sea cucumbers to spawn, identifying suitable algae and diatoms for the nutrition of the larvae and developing repeatable, cost-effective methods for rearing the larvae and juveniles to the stage where they are robust enough to transfer to coral reef habitats.*

*The project was approved by ACIAR on 27 March 1995. To date, work has involved construction of the necessary facilities at the Coastal Aquaculture Centre. These include accommodation for project staff, additional offices and wet laboratories, expansion of the hatchery, and an algal facility.*

*Recruitment of staff was finalised at the end of 1995. The new staff appointed to the project with ACIAR funds include a Scientist to complete the research tasks, a Research Associate dedicated to producing and isolating tropical algae and two Technical Aides. ICLARM will also contribute a B.Sc. (Hons) graduate and a Technical Aide to the project.*

*The project will concentrate on propagation of species of high value, particularly sandfish (*Holothuria fuscogilva*), although some research will also be done on surf redfish (*Actinopyga mauritiana*) as it is common near the Coastal Aquaculture Centre.*

*At the conclusion of the ACIAR project, ICLARM will seek funding to develop optimum release strategies for hatchery-reared sea cucumbers, and to test the effects of releases on existing fisheries for sea cucumbers.*



From Aquila Sea Products, Mozambique

1. *Pilot project: create a hatchery and a sea ranch for sea cucumbers in the Morrumbene area.*
2. *Migration of *H. scabra*.*

*I would like to report on a phenomenon which we witnessed; I wonder if anyone else has seen this before.*

*In the Morrumbene Estuarine Zone there are many channels where *H. scabra* is found, usually along with algae and sea grass. The currents are swift during incoming and outgoing tides.*

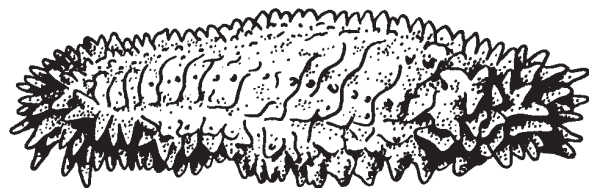
*On being disturbed in an area and some cucumbers eviscerated, and during the outgoing tide hundreds of cucumbers appeared above the sand and formed either a sort of a wheel shape with the body or contracted the body to form a sort of a thick cigar shape.*

*Then they proceeded to roll with current very rapidly and moved away at the speed of the water which reached an estimated seven knots. The next day there were no cucumbers evident in this area and we could not find where they had moved to. We have also found that juveniles and large cucumbers tend to live in separate areas and seldom mix in a given area.*



From Norman Reichenbach [Oceanographic Society of Maldives, P.O. Box 2075, Malé, Republic of Maldives, Tel: 960 325076, Fax: 960 325978]

*It is like the fishery here has gone the way other places have gone: lots collected for about five years and now several species are rare. There is a ban on collection of sea cucumbers using SCUBA. Otherwise no regulation. Many of the species like *H. fuscogilva* and *H. ananas* are recovering, (since they can live deep here (down to 40 m). In contrast, the marketable shallow-water species like *H. nobilis* and *A. mauritiana* can be quite rare due to continuing collection efforts.*



From S. M. Pauls

*I would greatly appreciate having copies of the Beche-de-Mer Information Bulletin No. 6 and 7. I need the information on the Galapagos illegal fishery of sea cucumber because these persons are now here in Venezuela (Caribbean South America) in some marine national parks, fishing clandestinely and in some islands here they are fishing illegally.*

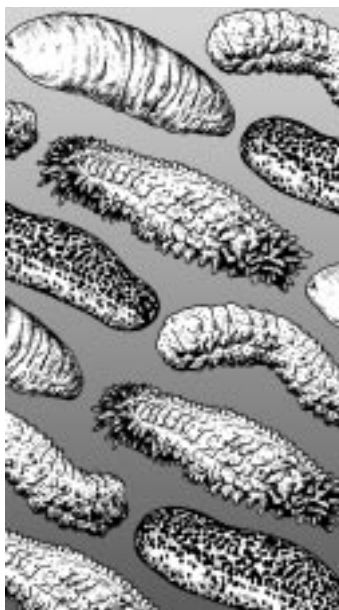
*Please, we need all information that you have, including contact persons with telephone/fax/e-mail numbers about the illegal fishing of sea cucumber in South America (Galapagos, Ecuador, Peru, etc.). We have here in Venezuela a serious problem now.*



From D.B. James [Tuticorin Research Centre, Central Marine Fisheries Research Institute, 90 North Beach Road, Tuticorin 628001, India]

*Dr D. B. James, Senior Scientist working at the Research Centre of the Central Marine Fisheries Research Institute, Tuticorin (Tamil Nadu, India) visited the Maldives as an FAO Consultant for 10 days. He made an initial visit to the mariculture site in Leamu Atoll to give recom-*

*mendations on spawning, larval rearing and production of seed stock for commercial tropical sea cucumbers. He has to visit the Maldives again in June 1996 for two weeks, and make a final visit in December 1996 for one month for seed production of sea cucumbers.*



B E C H E - D E - M E R

# Abstracts, Publications Workshops and Meetings



## Echinoderms Publications

*Compiled by Chantal Conand*

### **Les holothuries, ressource halieutique des lagons [English title: *Holothurians, fishery resource from the lagoons*].**

by Chantal Conand (1994). ORSTOM, Nouméa, Rapp. Sci. Tech. : Sci. Mer, 65. 86p.

This document is a synthesis of the present knowledge on the tropical Indo-Pacific Holothurians (*Echinodermata*), exploited for human consumption. The results on the biology and ecology of the

species are essentially based on the data collected in New Caledonia. After analysis of the recent trends of the world fisheries, the New Caledonian fishery is detailed and management proposals are given.



### **Growth estimates by the size distribution of sea cucumber, *Stichopus japonicus* Selenka, in the artificial pools in Toyasaki, Minamikayabe-chou, Southern Hokkaido.**

by HOSHIKAWA H., K. TAKASHI, Y. KONNO & T. MIYAGAWA (1995). Hokkaido Inst. Mariculture, Shikabe, Hokkaido 041-14, Japan, Scientific Reports of Hokkaido Fisheries Experimental Station 0 (46): 7-14.

The size distribution of a sea cucumber, *Stichopus japonicus* Selenka, was investigated in the artificial intertidal pools and rocky subtidal area in Toyasaki, Minamikayabe-chou, Southern Hokkaido. The den-

sity of juveniles was higher in the intertidal pools ( $6.67/0.25 \text{ m}^{-2}$ ) than in the rocky subtidal ( $0.33/0.25 \text{ m}^{-2}$ ). The body weights of 1+ and 2+ in October were estimated as ca. 10 g and ca. 40 g respectively.



### **Potential for asexual propagation of several commercially-important species of tropical sea cucumber (*Echinodermata*)**

by Norman Reichenbach & Steve Holloway [Oceanography Society of Maldives, P.O. Box 2075, Malé, Republic of Maldives]. In: Journal of the World Aquaculture Society. September 1995. 26 (3).

Six species of tropical sea cucumbers (*Echinodermata*) of high to moderate commercial value were evaluated as to their potential for being propagated asexually by induction of transverse fission. The species considered were *Thelenota ananas*, *Holothuria fuscogilva*, *Actinopyga mauritiana*, *A. miliaris*, *Stichopus chloronotus*, and *S. variegatus*. Rubber bands placed midbody on the sea cucumbers provided an effective yet simple technique to induce transverse fission. Although fission could be induced in all six species, only *T. ananas* and *S. chloronotus* had the ability to regenerate both anterior and posterior parts into whole animals.

Other species showed no or low potential for regeneration (*H. fuscogilva*, *A. mauritiana*) or regeneration of only the posterior part into whole animals (*S. variegatus*, *A. miliaris*). both *T. ananas* and *S. chloronotus* have survivorship of nearly 80% or greater. *S. chloronotus* regenerated anterior and posterior parts into whole animals within 3 months. In contrast, *T. ananas* regenerated the posterior part into a whole animal within 5 months while the anterior part was regenerated within 7 months. Consequently, weight recovery began earlier with *S. chloronotus* relative to *T. ananas*.

### Annual reproductive cycles of three sympatric species of intertidal holothurians (Echinodermata) from the coast of Eastern Cape Province of South Africa.

by Greg G. Foster and Alan N. Hodgson [Department of Zoology and Entomology, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa]. In: Invertebrate Reproduction and Development. (1995). 27 (1): 49–59.

Seasonality of reproduction of *Roweia stephensoni*, *Pseudocnella sykion* and *Neostichopus grammatus* was compared using gonad indexes, gonadal tubule diameters, egg diameters and the abundance of spermatozoa in tubules from January 1992 until August 1993.

All three species were *dioecious* and the population studies did not deviate from a 1:1 sex ratio. Body sizes at first sexual maturity were 2.5–2.9 cm<sup>3</sup> for *R. stephensoni* and *P. sykion* and 3.0–3.9 cm<sup>3</sup> for *N. grammatus*. The gonads of *R. stephensoni* and *P. sykion* consisted of a group of unbranched tubules of equal diameter, with males having more tubules of smaller diameter than females.

By contrast, the gonad of *N. grammatus* consisted of two tufts of multiple-branched tubules. All three species have annual reproductive cycles, and in *R. stephensoni* and *P. sykion*, gametogenesis occurred from March 1992 until August/September 1992, and gonad maturity was maintained until spawning in January 1993.

By contrast, in *N. grammatus* gametogenesis occurred from July 1992 until September 1992, and gonad maturity was maintained until spawning in December 1992/January 1993. In *R. stephensoni* and *P. sykion*, gonads never completely regressed whereas in *N. grammatus* gonads regressed after spawning.



### Annual reproductive cycle of the Japanese holothurian *Eupentacta chironjelmii*.

by Catalan, M. A. B., and M. Yamamoto (1994). In: Can. J. Zool. 72: 387–396.

The reproductive cycle of the small dendrochirote holothurian *Eupentacta chironjelmii* was studied in the intertidal zone of Aoshima Island, in the Seto Inland Sea of Japan, from July 1989 to January 1991. Reproductive status was assessed by the gonadal index method and histological analysis of the largest (tertiary) gonadal tubules.

The primary and secondary tubules are cryptic and difficult to find, so no reference to the animal's annual cycle in terms of gametogenesis is made. The gonad wall was thickest in September for female and October for males, when the gonadal index was at its peak. The rapid final stages of vitellogenesis in females (and completion of spermatogenesis in males) depleted reserves in the gonad wall, producing gametes that were spawned in October to December.

When gametes were spawned in December, the gonadal index and gonad wall thickness decreased. We suggest that the gonadal index reflects gonadal growth by oocyte production and an increase in gonadal wall thickness decreased.

In the laboratory, spawning occurred from midnight to 04h00, at ambient seawater temperature (12°C). Individuals elevated their anterior, oral end, waved their tentacles, and released gametes for about an hour.

Based on its large egg size ( $300 \pm 5 \mu\text{m}$  (mean  $\pm$  SE) diameter) and low fecundity ( $1500 \pm 10$  ripe oocytes per individual), we infer lecithotropic development with an abbreviated larval stage.





### Seasonal changes in biochemical composition of *Holothuria leucospilota* (Echinodermata)

by V. Jaya Sree, A. H. Parulekar, S. Whidulla & S. Y. Kamat, [National Institute of Oceanography, Dona Paula, Goa-403 004, India]. In: Indian Journal of Marine Sciences, June 1994, 23: 117–119.

Biochemical composition of body wall and gonads of *H. leucospilota* was analysed for protein, carbohydrate, lipid, ash, dry weight and colorific values and was discussed in relation to its spawning activities. Lipids constituted the major storage part

(2.5 to 30.55%) followed by proteins (1.08 to 3.74%) and carbohydrates (0.00006 to 0.00041%) in the body wall, but in gonads, the lipids, proteins and carbohydrates were 1.8 to 6.1%, 1.06 to 2.6% and 0.00001 to 0.00009% respectively.



### Reproductive biology of the sea cucumber *Holothuria atra* Jaeger 1833 (Echinodermata: Holothuroidea) in Laucala Bay, Fiji, with notes on its population structure and symbiotic associations

by Johnson Seeto. Thesis submitted in partial fulfilment of the requirements for the degree of, M.Sc. (Marine Science), the University of Otago, Dunedin, New Zealand, December 1994.

The reproductive periodicity of the sea cucumber *Holothuria atra* Jaeger 1833 in Laucala Bay, Fiji was determined at two sites—Makeluva and Sandbank Reefs—through measurement of gonad index, sperm activity, oocyte diameter, and gonad tubule diameter over a 14-month period.

Population structure and distribution patterns were compared between the two sites. Associates of *H. atra* were enumerated and factors affecting their abundance discussed.

*Holothuria atra* is dioecious. It is an asynchronous spawner in Fiji with a main breeding period in summer (September to December). Gonad indices and mean maximum gonad tubule diameter trends showed that the breeding season of *H. atra* is confined to a few months in summer. Sperm activity, gonad staging and oocyte-size frequency trends, however, showed that the breeding season was prolonged, with ripened oocytes present all year around.

The increase in gonad mass was periodic, but the ripeness of gonads was prolonged. Reproductive seasonality is probably influenced by temperature. Reproductive effort was greater in female *H. atra* from Makeluva Reef than females from Sandbank Reef.

However, there was no significant difference in reproductive effort between males at both sites. Size at first sexual maturity was about 80g gutted weight or 19 cm total length. *H. atra* is fissiparous at the sites studied but fission rates were very low.

*Holothuria atra* is the most abundant holothurian on Laucala Bay reefs with a unimodal size structure. There was a noticeable absence of females early in the study and no juveniles (< 6 cm) were found. The

Makeluva population of *H. atra* had a larger mean body size than the Sandbank population. *H. atra* occupying different zones of the same reef had different mean body sizes. The size distribution of the monthly samples was significantly different from each other at both sites.

The distribution of *H. atra* across Sandbank Reef was not random and density was related to exposure and substratum type. Females dominated the larger class sizes at both sites, but the sex ratios were approximately 1:1. The unreliability of measuring holothurians was not fully resolved, and it was suggested that gutted weight be used as the base parameter as it is the least variable. However, the minimum legal length should be designated by a legal wet length.

Symbiotic associations between *Holothuria atra* and invertebrate symbionts in Laucala Bay included the Polynoid scale-worm, *Gastrolepidia clavigera*, the sabelliphilid copepod, *Scambicornus modestus*, the harlequin crab, *Lissocarcinus orbicularis*, and the eulimid gastropods, *Peasistilifer gracilis*, *Peasistilifer nitidula*, and *Melanella aciculata*. Symbionts were more abundant at the Sandbank Reef site. In some months, host animals with larger body sizes had greater numbers of some symbiotic species.

Size limits for all processed holothurian species in Fiji are presently based on a minimum legal dry length of 7.62 cm which is an impractical measure of size. Size at first sexual maturity from this study is used to set minimum size limits based on length. Findings of parts of this study will help formulate new management practices and set the basis for reproductive studies of other commercially important holothurian species in Fiji.

## Echinoderm Conferences

*Compiled by Chantal Conand*

The 9th International Echinoderm Conference will be held in San Francisco, from 5 to 9 August 1996. For information contact Dr R. Mooi, Department of Invertebrate Zoology, California Academy of Sciences, Golden Gate Park, CA 94118-4599, San Francisco, or e-mail: rmooi@cas.calacademy.org.

During the Conference, a symposium on Echinoderm fisheries and mariculture is scheduled, as it seems that now is the right time to address some of the issues of exploitations, regulations, stock enhancement and culture.

If you are interested in presenting a talk or a poster, could you please send a tentative title to C. Conand (e-mail: conand@univ.reunion.fr) and contact Rich Mooi to receive the first circular and registration material. More information on this Conference [provided by Dr Rich Mooi, Conference organiser] is presented below.

### 9TH INTERNATIONAL ECHINODERM CONFERENCE, 5-9 AUGUST 1996, SAN FRANCISCO, CALIFORNIA, USA

The Scientific Committee and the host institution, the California Academy of Sciences are pleased to invite your participation in the 9th International Echinoderm Conference (9th IEC).

All correspondence regarding registration, accommodation, cancellation, payment, etc., pertaining to the 9th IEC should be addressed to:

Rich Mooi, Chair, 9th IEC  
Department of Invertebrate Zoology & Geology  
California Academy of Sciences  
Golden Gate Park  
San Francisco, California 94118-4599 USA  
Fax: 415-750-7090; Phone: 415-750-7086  
E-mail: rmooi@cas.calacademy.org

#### **The Scientific Committee:**

- Dan Blake, University of Illinois at Champaign-Urbana;
- Olaf Ellers, University of California at Davis  
Gordon Hendler, Natural History Museum of Los Angeles County;
- James Kelley, San Francisco State University;
- Tom Niesen, San Francisco State University
- John Pearse, University of California at Santa Cruz;
- Vicki Pearse, University of California at Santa Cruz;
- Malcolm Telford, University of Toronto;

- Robert Van Syoc, California Academy of Sciences;

The 9th IEC will be held at the Seven Hills Conference Center on the campus of San Francisco State University [The University is in the southwestern part of the city of San Francisco].

The Scientific Committee would be happy to provide official letters of invitation to participate in the 9th IEC. These letters are intended to be of assistance to potential participants in obtaining funding, and should in no way be considered a commitment on the part of the Scientific Committee to provide financial support.

Each conferee planning to attend any of the sessions is required to register individually for the conference by filling out the Registration Form provided (ASK DR MOOI FOR A COPY), and to pay registration fees in full [Name tags signifying registered conferees will be issued.] Additional copies of registration materials are available upon request. Feel free to photocopy these materials.

Doctoral and pre-doctoral students can qualify for the lower fee if their registration is accompanied by the signature of their thesis adviser in the appropriate space on the Registration Form. Unregistered guests must register under the name of a conferee. The Registration Form must be completed and returned by 1 May 96.

#### **Registration fees are:**

	Before 1/5/96	After 1/5/96
Conferee	US\$175	US\$215
Student Conferee	US\$150	US\$190
Unregistered Guest	US\$40	US\$80

The official language of abstracts, the proceedings, posters, and communications for the 9th IEC is English.

#### ***Schedule of events:***

- 4/8/96: Afternoon: check-in and registration;
- 5/8/96: Morning: Welcome address & Symposium  
Afternoon: Contributed papers;
- 6/8/96: Morning: Symposium  
Afternoon: Contributed papers
- 7/8/96: Morning: Poster session  
Afternoon: Free time
- 8/8/96: Morning: Contributed papers, poster session continued  
Afternoon: Contributed papers, poster session continued
- 9/8/96: Morning: Contributed papers  
Afternoon: Symposium and closing address

#### ***Call for abstracts:***

All presentations (oral communication, symposium talk, or poster) **MUST** be accompanied by an abstract, in **ENGLISH**. Please note that the abstract is limited to 350 words in length. Submission of abstracts by Electronic mail is encouraged [send the abstract as an ordinary message, and not as an attached file].

#### ***Oral contributed papers:***

Oral communications that are part of contributed paper sessions will be 20 minutes long (15 minutes for the presentation, 5 minutes for questions). Overhead projectors, slide projectors, and trays for standard 35 mm slides will be available. The lecture hall in which symposia will be held has VHS video facilities. VHS equipment for other lecture halls can be acquired if a strong demand for them is demonstrated by conferee responses on the Registration Form.

#### ***Posters:***

Posters will go up on the morning of Wednesday 7 August and be on display until the afternoon of Thursday 8 August, at which time they must be taken down. A session dedicated to the posters **ONLY** (not in parallel with other sessions) will occur on the morning of 7 August.

#### ***Symposia:***

In addition to the contributed paper sessions, three special symposia are planned. Each of them will comprise a series of talks of approximately 25 minutes from each of 6 to 10 invited speakers. These symposia include:

- Major Events in the Evolution of the Echinoderms [G. Wray, organiser];
- Mutable Collagenous Tissues [O. Ellers & M. Telford, organisers];
- Echinoderm Fisheries and Mariculture [C. Conand, organiser]

#### ***Publication of proceedings:***

All conferees, whether presenting an oral contributed paper, symposium talk, or poster are invited to submit papers for publication in the proceedings volume for the 9th IEC. In keeping with previous IECs, A.A. Balkema has agreed to publish this volume, which will be edited by Dr Rich Mooi and Malcolm Telford.

Conferees wishing to publish their contribution in this volume should prepare 2 copies of a manuscript for submission to the Scientific Committee at the time of the conference.

Extra copies of the proceedings will be available from A.A. Balkema, P.O. Box 1675, NL-3000 BR Rotterdam, Netherlands (ph: 31 10 4145822; fax: 3110-413-59-47).



